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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVI. NOVEMBER 13, 1885. No. 1

EDWIN DUNKIN, F.R.S., President, in the Chair.

The Rev. Stephen Henry Saxby, M.A., East Clevedon, Somerset, was balloted for, and duly elected a Fellow of the Society.

Proposal for Photographing the Heavens.

(*Letter to the President, from Admiral Mouchez.*)

Monsieur le Président,—J'ai l'honneur de vous prier de vouloir bien présenter à votre illustre Société la photographie agrandie d'une partie de la voie lactée et le cliché obtenu directement avec le nouvel appareil photographique créé à l'Observatoire de Paris pour construire les cartes écliptiques. Cet appareil, muni d'un objectif spécial de $34^{cm.}$ de MM. Paul et Prosper Henry, semble avoir réalisé un très-remarquable et important progrès dans la photographie des étoiles.

Avec une heure de pose, nous obtenons les étoiles de 14^{e} et de 15^{e} grandeur. Si vous regardez le cliché avec une forte loupe ou mieux au microscope, vous verrez que toutes les petites étoiles sont triplées et les autres ont un contour un peu vague; cela provient de ce qu'on a fait 3 poses de 1 heure chacune, à $4''{\cdot}5$ de distance de manière à obtenir 3 images de la même étoile en forme de triangle. On est certain ainsi de ne pas confondre des taches ou accidents de plaque avec des étoiles. Sur une étendue de $2°\ 15' \times 3°$, on compte près de 5,000 étoiles sur le cliché.

Notre nouvel appareil photographique est principalement destiné à continuer les cartes écliptiques; mais je pense, Monsieur le Président, que vous jugerez, comme le savant et habile

Directeur de l'Observatoire du Cap, M. Gill, et comme moi, que le moment est venu d'utiliser un semblable progrès pour entreprendre la carte complète de la voûte céleste en établissant une entente entre 6 ou 8 observatoires bien placés dans les deux hémisphères.

Nos clichés pouvant représenter 7° superficiels, il en faudrait 6,000 pour obtenir toute la voûte céleste, et qui, réunis par 4, donneraient 1,500 feuilles semblables aux cartes écliptiques de l'Observatoire de Paris.

Six, huit, ou dix ans au plus permettraient de réaliser ce vaste projet et de léguer aux siècles futurs une image très-exacte du ciel à la fin du 19e siècle. La très-haute importance d'un tel projet, les nombreuses découvertes qu'il promet aux astronomes de l'avenir, m'engagent à vous prier de le soumettre à l'étude de votre illustre Société et de chercher, si on le croit réalisable, quel serait le moyen d'établir cette entente pour en préparer et en poursuivre l'exécution.

Veuillez agréer, Monsieur le Président, l'assurance de ma haute considération,

Le Contre-Amiral, Directeur de l'Observatoire,

E. Mouchez.

Observatoire de Paris:
le 20 Juin, 1885.

On Dr. Wilsing's Experimental Examination of the Wedge Photometer; and (II.) On the Degree of Accuracy attainable by means of that Instrument. By Prof. C. Pritchard, D.D., F.R.S.

In the *Astronomische Nachrichten* for Sept. 14, 1885 (No. 2680), Dr. Wilsing, of Potsdam, has honoured me by a very able and very elaborate criticism on the Wedge Photometer, extending over eighteen columns, and conceived in a fair and discriminating spirit. Dr. Wilsing's remarks apply chiefly to—

1. The possible influences on the measured magnitude of the fainter stars, when the brightness of the ground forms an important fractional part of the total intensity.
2. To non-invariability of the eye for any length of time.
3. To the effect of colour.

Such criticisms of new work are very valuable, and are so many posts on the road towards the establishment of fact. When Dr. Wilsing wrote this article on July 1 he was not aware of my paper, which was read and discussed at the June meeting of the Royal Astronomical Society; moreover, he was not in possession of that portion of the Oxford Photometry which applied to stars of the fifth and sixth magnitudes, and it is mainly on these stars of a fainter lustre, that some question has arisen as to the effect of the luminosity, greater or less, of the background, which he

considers, with Prof. Pickering, may affect the concluded magnitudes of the fainter stars. The whole catalogue, formed on Argelander's *Uranometria Nova*, is now completely printed, and will be published, together with an Introduction, by the Delegates of the Clarendon Press, by the time the present communication reaches the Fellows of the Society in print.

I will now take the leading points of Dr. Wilsing's criticism into consideration, *seriatim*, and make such remarks as I conceive may closely bear upon the subjects, and be interesting to the Society.

Dr. Wilsing commences his critique by referring to physiological questions regarding the impressions of light on the eye; especially in relation to Fechner's law and experiments connected therewith. Fechner has virtually translated the physical relations of light, in its passage through media, into nerve-impressions on the brain; and he has extended them with some ingenuity to other sensations besides those of light. With regard to these obscure physiological relations, I desire to keep aloof from them in this communication to the Royal Astronomical Society, and I propose to confine myself solely to the region of experimental and observational fact.

The results of Fechner's experiments, so far as I understand them, are these. In regard to intensities of light, not extreme in their character, he states that an alteration in the intensity of light will be perceptible to the eye, if it amount to about one-hundredth of the whole. I confess I was at first disinclined to suppose that so small a variation was within the limits of appreciation. I resolved therefore to repeat Fechner's experiment, and it has been so repeated at the University Observatory. Two contiguous shadows were formed on white paper, by two lights, which effectively differed, approximately in the ratio of 100 : 1. The difference between the illuminations represented by 100 and 101 was just perceptible, and it was only with hesitation that it could be said the same remark was not applicable even to the ratio 120 : 121. The experiment was varied by *looking through tracing paper*, instead of confining it to *reflected* light, and with approximately the same results. We are therefore constrained to admit that such feeble differences of light are in reality capable of producing impressions on the visual organs under the conditions aforesaid.

There is also another remark of Fechner's which may be found to bear more or less on stellar photometry, to the effect that it is the *ratio* of the difference to the whole which is capable of making visual impression, rather than the feeble illumination in and by itself. This fact was virtually, though not formally, known to the Greek astronomers, who divided their successive magnitudes into thirds, whether they referred these subdivisions of light to the first or to the sixth magnitude; and it will be remembered that one-third of the light of a first magnitude star is in intensity equal to about *thirty* times the whole light of a

sixth magnitude star. This may appear a somewhat startling remark, nevertheless it expresses a fact.

Now it is mainly on this capacity of the human eye for the discrimination of feeble differences in the ratio of two lights, that it has been conceived that the background on which stars are viewed may exercise an influence on the determination of the magnitude of feeble stars, not much brighter than the background itself, on which they are projected. The preceding considerations are entirely theoretical as applied *to the case of stars in the sky*, with which alone we have now to deal. In my last communication to the Society I showed that, so far as *Polaris** was concerned, its apparent magnitude was not affected in the telescope by the phase of the Moon; and it was also shown that on making a selection of stars in various parts of the heavens, differing greatly in stellar density, no effects of this varying density could be detected by a comparison between the resulting magnitudes in the Harvard and Oxford tables to the fourth magnitude. Prosecuting this inquiry still further into the case of the stars of the fifth and sixth magnitudes, now that my whole catalogue is completed, I have found that this same remark still holds as respects the non-interference of background or stellar density; always remembering two facts—first, that the comparison is made with the Harvard Catalogue; and secondly, that the least difference of light measurable in stellar photometry, whether by the wedge or any other known sidereal photometer, does not go beyond the thirteenth or fourteenth of a magnitude, instead of reaching nearly to the hundredth of a magnitude, as suggested by Fechner and confirmed at Oxford. This latter remark is of prime importance. The feeble differences in light ratio of 100 : 1 referred to in Fechner's experiment, apply solely to large illuminated *surfaces*, viewed with both eyes, and not to mere *points* of light viewed with such instrumental appliances as exist in sidereal photometry. Even in Seidel's instrument, where the stars are expanded into discs, no greater delicacy of discrimination existed than in the Wedge, or in the Zöllner, or in the Meridian Photometer. Sidereal photometry, definite and beautiful as I regard it to be, in its recent aspects, is not of such delicacy that tests and strictures which properly apply to such inquiries as Fechner's are legitimately applicable, or even possible, when applied to the stars. Moreover, minute disturbing influences which may properly be taken into account in experiments and theoretical inquiries regarding the measurability of impressions of light in general, are negligible, and in fact *must* be neglected in all cases of sidereal photometry.

* If it be remarked that the effect of the moonlight is there examined in reference only to so bright a star as *Polaris*, it may be sufficient to state that ordinary scattered moonlight is extinguished by the wedge, in the 4-inch telescope, at less than an inch from the thinner end, whereas a star of the sixth magnitude is extinguished therein, at a place on the wedge more than two inches and a half from the extremity.

The presence of other stars in the field of the telescope, as limited by the photometer, produces a background of a different character from that already described. This field of view in the 4-inch telescope is confined to a circle of 0·02 inches diameter in the focal field, equivalent to about 80″. A reference to Argelander's charts will indicate the fact that in very few instances indeed will so contracted a field comprise with a sixth magnitude star any other star ranging from the seventh to the tenth magnitude. A seventh magnitude is very rare: if it be within 20″ of the star to be measured, then it would be placed in the category of double stars, and its character would be referred to in the Notes. It would, if viewed as one point of light, coalesce with a sixth magnitude, and would have a combined result of 5·6. If, on the other hand, the small star, or the two or three small stars in the field, be detached from the brighter star they would produce distinct impressions on the retina, *and would be completely extinguished by the wedge* long before the extinction of the brighter, and could produce absolutely no influence on its measure in the photometer. Precisely the same sort of reasoning applies to the measurement of fainter stars in a larger telescope, say of twelve inches or any greater aperture. The photometric field in such telescopes is still more restricted, and the very faint stars possibly accompanying the one to be measured, would either coalesce as a double or multiple star, and be noted as such; or they would be extinguished by the wedge long before the extinction of the brighter.

The effect of the coalescence of two stars upon the magnitude of the brighter is shown in the following short table:—

Difference in Mag. of two Stars whose lights coalesce.	Resulting addition of brightness to the brighter Star in Mag.	Difference in Mag. of two Stars whose lights coalesce.	Resulting addition of brightness to the brighter Star in Mag.
0·0	0·75	2.0	0·16
0·5	0 53	3·0	0·07
1 0	0·37	4 0	0·03
1·5	0·25	5·0	0·01

These considerations are sufficient to indicate the freedom of this form of photometer from the influence of the greater or less density of stars illuminating various regions of the heavens (always within the limits of accuracy prescribed).

I come now to another point insisted on by Dr. Wilsing—viz. the varying sensitiveness and fatigue of the observer's eye in the course of observations during any one night, and at remotely distant intervals of time. This is a fair question, requiring a fair consideration. The consideration which I shall give it is, as in other parts of this paper, a practical one; and it does not extend to such extreme cases as some of those referred to by Dr. Wilsing —viz. to a continuation of the observations throughout *five* hours on a single night. In order to assure myself of the non-existence

of this source of error, a large number of extinctions of *Polaris* made on separate nights have been examined. These extinctions of *Polaris* are usually made three times on each night—viz. at the beginning, the middle, and the end of the series. No trace of a systematic difference is found, indicating symptoms of varying sensitiveness of the observer's eye, depending on these sequences of time. Moreover, as the measures are strictly differential, and as the mean of the three sets of readings of the extinction of *Polaris* (which rarely differ much *inter se*) is used for all the observations of the series, the mean condition of the eye is maintained throughout. In point of fact, there are continual breaks in the work of observation, connected with the shifting of the dome, the identification of the stars, and recording the results; and the whole series is rarely permitted to occupy more than three hours in the night. All these circumstances combine to prevent any undue strain on the eye of the observer.

Regarding the question of colour, another point in Dr. Wilsing's critical examination, I can only repeat what has been so strongly insisted upon in vol. xlvii. of the Society's *Memoirs*, viz. that so far as colours not very salient are concerned, the wedge interval for them is identical with that for light in general. At the same time I cannot repress the conviction that the photometry of intense colours is not as yet accomplished.

II.

On the Amount of Accuracy attainable by the Wedge Photometer.

In order that there may be no misapprehension as to the actual amount of accordance existing between the individual measures, or between the several determinations of adopted magnitudes derived from taking the mean of the former, I append the two following tables. The first gives the detail of one night's work, of an average character, on the extinction of *Polaris*, and on the determination of the magnitude of one star (72 *Tauri*), as the result of the mean of the four sets of five measures which form the usual or normal method of the two observers. Sufficient explanation is afforded by the headings of the several columns.

The second table gives the results of ten or twelve nights' repetition of the determinations of the magnitude of each of sixteen selected stars. They comprise among them, as a matter of interest, the seven *lucidæ* in *Ursa Major*, and also μ and R. 204 *Andromedæ*; the latter were used in the determination of the varying magnitude of the *Nova* in the *Andromeda* nebula, from nearly its first outburst to the time when it seemed to settle down into a star of approximately the tenth magnitude.

TABLE I.

Original Observations for the Determination of the Difference of Magnitude of Polaris and 72 Tauri.

Date and Instrument employed.	Original Readings of Wedge for extinction of *72 Tauri*.	Mean Wedge Readings of extinction of *Polaris* at beginning, middle, and end of series.	Wedge Interval in inches.	Magnitude equivalent to Wedge Interval.	Assumed Magnitude of *Polaris*.	Resulting Magnitude of *72 Tauri*.	Finally adopted Mean Mag.
	in.	in.					
1884, Dec. 20.	2·65	4·602					
With Wedge A on 4-inch	·53	·592					
telescope.	·72	·606					
	·65						
	·71						
Mean	2·652	4·600	... ...	3·56	2·05	**5·61**	
With Wedge A on 2-inch	1·90	3·828					
telescope.	·83	·868					
	·79	·840					
	·92						
	·86						
Mean	1·862	3·845	... ...	3·69	2·05	**5·74**	**5·65**

Date and Instrument employed.	Original Readings of Wedge for extinction of 72 *Tauri*.	Mean Wedge Readings of extinction of *Polaris* at beginning, middle, and end of series.	Wedge Interval in inches.	Magnitude equivalent to Wedge Interval.	Assumed Magnitude of *Polaris*.	Resulting Magnitude of 72 *Tauri*.
	in.	in.				
With Wedge B on 3-inch	1·30	2·682				
telescope.	·27	·698				
	·29	·682				
	·34					
	·26					
Mean	1·292	2·687	1·395	3·62	2·05	**5·67**
With Wedge B on 1½-inch	0·71	2·076				
telescope.	·60	·084				
	·74	·062				
	·70					
	·79					
Mean	0·708	2·074	1·366	3·54	2·05	**5·59**

TABLE II.

Magnitudes of Stars observed on many Nights.

Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.
	β Ursæ Majoris.	
2·913	2·14	20
3·062	2·20	10
3·070	2·18	10
3·078	2·15	10
3·081	2·09	10
3·089	2·09	10
3·092	2·10	10
5·467	2·19	10
5·483	2 27	10
5·485	2·30	10
Mean	**2·17**	
Average deviation	0·06	

Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.
	α Ursæ Majoris.	
2·913	1 90	20
3·062	1·92	10
3·070	1·85	10
3·078	1·90	10
3·081	1·98	10
3·089	1·89	10
3·092	1·92	10
5 467	1·88	10
5·483	1·81	10
5·485	1·80	10
Mean	**1·89**	
Average deviation	0·04	

	γ Ursæ Majoris.	
2·938	2·34	20
3·062	2·31	10
3·070	2·27	10
3·095	2·20	10
3·100	2·31	10
5·467	2·45	10
5·483	2·19	10
5·485	2·28	10
5·505	2·47	10
5·514	2·13	10
5·519	2·15	10
5·533	2·45	10
Mean	**2·30**	
Average deviation	0·09	

	δ Ursæ Majoris.	
2·938	3·39	20
3 062	3·37	10
3·070	3·36	10
3·095	3·36	10
3·100	3·53	10
5·467	3·40	10
5·483	3·43	10
5·485	3·55	10
5·505	3·34	10
5·514	3·56	10
5·519	3·37	10
5·552	3·35	10
Mean	**3·41**	
Average deviation	0·06	

	ε Ursæ Majoris.	
2·938	1·80	20
5·467	1·70	10
5·483	1·91	10
5·485	1·75	10

	ζ Ursæ Majoris.	
2·938	1·95	20
5·467	2·08	10
5·483	2·18	10
5·485	2·14	10

Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.
	ε Ursæ Majoris.	
5·505	1·70	10
5·514	1·79	10
5·519	1·89	10
5·533	1·80	10
5·552	1·85	10
5·565	1·79	10
Mean ...	... **1·80**	
Average deviation	0·06	

Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.
	ζ Ursæ Majoris.	
5·505	2·16	10
5·514	2·04	10
5·519	2·23	10
5·533	2·02	10
5·552	2·09	10
5·565	2·03	10
Mean ...	... **2·09**	
Average deviation	0·07	

	η Ursæ Majoris.	
2·957	1·75	20
5·467	1·69	10
5·483	1·79	10
5·485	1·83	10
5·505	1·67	10
5·514	1·79	10
5·519	1·88	10
5·533	1·80	10
5·552	1·75	10
5·565	1·73	10
Mean ...	... **1·77**	
Average deviation	0·05	

	β Cassiopeiæ.	
2·835	2·32	20
5·514	2·34	10
5·519	2·40	10
5·533	2·35	10
5·552	2·36	10
5·565	2·52	10
5 571	2·56	10
5·574	2·43	10
5·697	2·42	10
5·724	2·32	10
Mean ...	... **2·40**	
Average deviation	0·07	

	γ Cassiopeiæ.	
2·810	2·19	20
5·514	2·27	10
5·519	2·22	10
5·533	2·21	10
5·552	2·42	10
5·565	2·50	10
5·571	2·55	10
5·574	2·34	10
5·724	2·34	10
5·732	2·24	10
5·738	2·14	10
5·749	2·27	10
5·751	2·27	10
Mean ...	... **2·23**	
Average deviation	·09	

	δ Cassiopeiæ.	
2·810	2·89	20
5·514	2·89	10
5·519	2·94	10
5·533	2·93	10
5·552	3·02	10
5·565	2·88	10
5·571	2·91	10
5·574	2·92	10
5·697	2·84	10
5·724	2·81	10
5·732	2·94	10
Mean ...	... **2·91**	
Average deviation	·04	

Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.
	α Cygni.	
2·430	1·38	20
3·068	1·31	10
3·148	1·33	10
3·164	1·28	10
3·167	1·25	10
3·170	1·34	10
5·533	1·39	10
5·552	1·42	10
5·565	1·25	10
5·574	1·30	10
Mean	**1·33**	
Average deviation	·05	
	η Persei.	
2·699	4·14	20
2·702	4·13	20
2·705	4·09	20
2·708	4·19	20
3·103	4·14	10
3·106	4·05	10
3·108	4·13	10
3·169	4·13	10
3·174	4·09	10
3·207	4·14	10
Mean	**4·12**	
Average deviation	·03	
	μ Andromedæ.	
2·693	3·98	20
5·692	3·94	10
5·692	3·89	10
5·697	3·90	10
5·724	3·95	10
5·724	3·96	10
5·732	3·85	10

Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.
	γ Cygni.	
2·430	2·28	20
3·068	2·23	10
5·533	2·35	10
5·552	2·31	10
5·565	2·17	10
5·574	2·18	10
5·724	2·31	10
5·732	2·18	10
5·738	2·21	10
5·749	2·31	10
5·751	2·22	10
Mean	**2·28**	
Average deviation	·06	
	α Andromedæ.	
2·685	2·01	20
2·693	2·05	20
2·697	2·09	20
5·533	2·02	10
5·552	2·24	10
5·565	2·17	10
5·574	2·02	10
5·697	2·00	10
5·721	2·05	10
5·732	2·03	10
5·749	2·02	10
5·751	2·05	10
Mean	**2·05**	
Average deviation	·05	
	R. 204.	
4·012	5·92	20
5·697	5·95	10
5·724	6·11	10
5·724	6·03	10
5·732	6·01	10
5·735	5·92	10
5·738	5·87	10

Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.	Date of Observation 1880.	Individual Magnitudes.	No. of Extinction.
	μ Andromedæ.			*R.* 204.	
5·735	3·91	10	5·749	5·86	10
5·738	3·96	10	5·752	5·88	10
5·749	3·91	10	5·757	5·99	10
5·752	3·98	10	5·782	5·98	10
5·757	3·97	10	5·792	3·97	10
5·782	3·93	10			
5·792	3·97	10			
Mean ...	... 3·94		Mean ...	... 5·96	
Average deviation	·03		Average deviation	·06	

From these two tables conclusions of considerable interest and importance may be derived in relation to the amount of accuracy to be looked for in the determinations of magnitude published in the *Uranometria Nova Oxoniensis*.

On inspection of the second table, it appears that very little improvement in accuracy is gained in general by repeating the measures through many nights, provided the first twenty usual determinations are made on a night free from abnormal or saliently varying meteorological conditions. Nevertheless, a small number of discordances do, and I fear must, occasionally occur, and nothing but re-observations can eliminate such errors from any catalogue. The final results, so far as my powers of scrutiny extend, exhibit no symptoms of systematic error. The average deviation from the mean for all these repeated observations on so many nights still remains approximately the same as for stars measured in the normal manner on a single fair night, viz. about 0·06 magnitude; and this, I think, represents in reality the utmost average delicacy attainable with the Wedge Photometer, and I claim for it an accuracy at least as great as has been yet attained by any other instrument.

This magnitude 0·06 corresponds to about $\frac{1}{18}$ of the whole light of the star whose magnitude is measured; and it must be remembered that it involves the combination of the error made in the extinction of *Polaris* with that of the star. In order to compare this result with the accuracy attained in other photometrical experiments such as Fechner's, &c., it will be necessary to divide this amount by $\sqrt{2}$, which gives $\frac{1}{25}$ of the light, as the limit of sensitiveness of this species of observation. As we have already seen, the utmost delicacy of appreciation attainable by shadows, as exhibited by my own repetition and modification of Fechner's experiment, is $\frac{1}{100}$ of the whole light. Bouguer sets it down, from his own researches, as $\frac{1}{64}$ approximately. Mr. Dixon, in some recent photometrical experiments on lighthouse illuminants, regards it as practically about $\frac{1}{50}$. Such being the

case, even when the lights are on surfaces of appreciable extent, and viewed leisurely by both eyes, $\frac{1}{25}$ of the whole light is, after all, a not unsatisfactory amount of discriminating power in the case of a star viewed with a single eye as a point, and with that eye under a certain degree of instrumental constraint.

Lastly, I append a list—I wish it were a shorter one—of all the stars in the Northern Hemisphere where I find a difference exceeding one-third of a magnitude between the Harvard and Oxford catalogues, referred to the same scale in relation to *Polaris*. Wherever I found the existence of this amount of difference, I felt it desirable to repeat my observation. In almost every instance, as shown by the notes in my *Uranometria*, I have (within the prescribed limit of error) recovered the determination previously made. This is in accordance with the remark made respecting the sixteen stars set down in Table II. Still I do not by any means intend to affirm a conviction that my own results are always unimpeachable. It may be remarked that these stars are scattered through all magnitudes, and over all parts of the sky. They amount to about five per cent. of the whole number observed, and it must not be forgotten that these discordances in the two catalogues are derived from differences of measures of *two* stars, each affected with its own error of observations; in point of fact there are four independent fallible measures in each of the discordances arising from the comparison of the two catalogues.

TABLE III.

List of Stars in the Harvard and Oxford Catalogue (Uranometria Nova Oxoniensis) in which the difference exceeds one-third of a Magnitude.

Name of Star.	Mag. at Oxford.	Mag. at Harvard −0·1.	Difference.
ι Androm.	4·56	4·20	0·36
32 Aquarii	5·60	5·14	·46
P. XXI. 421	6·07	5·75	·32
67 Aquarii	6·45	6·10	·35
P. XXII. 250	6·05	5·67	·38
χ Aquarii	5·52	5·05	0 47
5 Aquilæ	6·09	5·65	·44
ν Aquilæ	5·08	4·70	·38
τ′ Arietis	5·42	5·08	·34
R. 1328	5·85	5·44	·41
19 Aurigæ	5·42	5·00	0·42
θ „	3·03	2·57	·46
κ „	4·81	4·36	? Var.
α Boötis	+0·69	+1·07	·38
B. A. C. 4830	6·10	5·74	·36

Name of Star.	Mag. at Oxford.	Mag. at Harvard −0·1.	Difference.
ν Boötis	4·64	4·99	0·35
P. III. 51	4·55	4·06	·49
P. III. 177	5·03	4·65	·38
3 Camelop.	5·78	5·27	·51
31 „	5·52	5·13	·39
μ Cancri	5·55	5·15	0·40
ψ „	6·02	5·68	·34
P. VIII. 67	5·38	4·99	·39
o Cancri	5·53	5·11	·42
β Can. Ven.	4·53	4·20	·33
R. 3074	5·96	6·34	0·38
Sirius	+ 1·95	+ 2·53	·58
η Can. Min.	5·66	5·21	·45
1 Cassiop.	5·22	4·89	·33
4 „	5·49	5·07	·42
P. o. 118	5·48	4·90	0·58
ξ Cassiop.	5·19	4·70	·49
P. o. 162	5·70	5·26	·44
θ Cassiop.	4·68	4·33	·35
50 „	4·40	3·96	·44
ν Cephei	4·84	4·40	0·44
ε „	4·76	4·14	·62
B. A. C. 8180	5·98	5·61	·37
13 Comæ	5·47	4·99	·48
16 „	5·39	4·99	·40
μ Aquilæ	5·10	5·58	? Var.
δ Coronæ	4·87	4·46	·41
15 Cygni	5·42	4·93	·49
22 „	5·14	4·57	·57
25 „	5·52	5·10	·42
47 Cygni	5·03	4·67	0·36
λ „	4·90	4·47	·43
55 „	5·39	4·90	·49
ε Delphini	3·59	4·03	·44
π Draco.	4·84	4·45	·39

Name of Star.	Mag. at Oxford.	Mag. at Harvard −0·1.	Difference.
P. XX. 376	6·15	5·80	0·35
4 Equulei	5·76	6·08	·32
ν Geminor.	4·33	3·88	·45
30 „	5·19	4·52	·67
33 „	5·75	5·34	·41
ρ Geminor.	4·45	4·05	0·40
o „	5·02	4·57	·45
β „	1·36	1·02	·34
λ Herculis	4·70	4·19	·51
87 „	5 73	5·29	·44
W. B. XVII. 1438	6·17	5·56	0·61
98 Herculis	5·68	5·28	·40
W. B. XVIII. 76	5·91	5·54	·37
η Hydræ	4·42	4·07	·35
ρ „	4·66	4·21	·45
L. 17835	6·00	5·51	0·49
1 Lacertæ	4·64	4·04	·60
W. B. XXII. 1133	6·06	5·50	·56
81 Leonis	5·77	5·37	·40
86 „	6·03	5·62	·41
89 Leonis	6·09	5·63	0·46
2 Lyncis	4·73	4·23	·50
21 „	4·88	4.47	·41
P. VII. 169	5·50	5·10	·40
B. A. C. 6203	5·66	5·24	·42
W. B. XVIII. 794	5·62	5·29	0·33
θ Lyræ	4·64	4·24	·40
8 Monocerotis	4·89	4·30	·59
12 „	6·03	5·59	·44
P. VI. 257	5·98	5·62	·36
68 Ophiuchi	4·75	4·32	? Var.
67 „	4·35	3·92	0·43
70 „	4·35	4·01	·34
π^2 Orion.	4·86	4·32	·54
π^3 „	3·62	3·23	·39

Name of Star.	Mag. at Oxford.	Mag. at Harvard −0·1.	Difference.
τ Orion.	3·95	3·55	0·40
υ „	4·91	4·56	0·35
42 „	5·45	4·50	? Var.
45 „	5·78	4·85	? Var.
W. B. V. 1048	6·00	5·58	0·42
χ′ Orion.	5·06	4·55	0·51
L. 11382	5·04	4·63	? Var.
μ Orion.	4·69	4·19	0·50
15 Pegasi	5·92	5·53	·39
ι „	4·24	3·89	·35
52 Pegasi	6·22	5·76	0·46
70 „	5·04	4·55	·49
16 Persei	4·77	4·33	·44
σ „	4·73	4·29	·44
ο „	4·40	3·91	·49
W. B. III. 942	5·93	5·60	0 33
27 Piscium	5·30	4·93	·37
47 „	4·94	5·27	·33
58 „	6·00	5·60	·40
τ „	4·24	4·63	·39
λ Serpentis	4·68	4·25	0·43
π „	4·48	4·89	·41
59 „	5·50	5·11	·39
15 Sextantis	4·89	4·41	·48
D. M. + 21° No. 539	5·99	5·58	·41
P. III. 215	6·07	5·58	0·49
P. III. 234	5·80	5·45	·35
37 Tauri	4·84	4·35	·49
ω „	5·08	4·55	·53
71 „	5·03	4·51	·52
P. IV. 82	6·00	5·58	0·42
109 Tauri	5·44	5·05	·39
115 „	5·69	5·28	·41
121 „	5·77	5·33	·44
B.A.C. 516	5 66	5·27	·39

Name of Star.	Mag. at Oxford.	Mag. at Harvard −0·1.	Difference
10 Trianguli	5 55	5·19	0·36
24 Ursæ Majoris	4·92	4·49	·43
φ „	4·73	4·33	·40
B.A.C. 3821	6·06	6·47	·41
„ 3985	5·58	5·23	·35
5 Ursæ Minoris	4·72	4·19	0·53
P. XVI. 182	5·92	5·44	·48
ξ Virginis	5·21	4·82	·39
64 „	5·97	5·58	·39
71 „	5·93	5·56	·37
84 Virginis	6·00	5·63	0·37
P. XIV. 12	5·44	4·87	? Var.
109 Virginis	4·04	3·62	·42
110 „	4·99	4·46	·53
12 Vulpec.	5·49	4·92	·57
13 Vulpec.	4·97	4·56	0·41
B.A.C. 6966	5·09	4·66	·43
λ Ceti	4·93	4·50	·43
31 Leonis	4·87	4·50	·37
χ „	4·98	4·62	·36

On summing up the details of the two catalogues as completed, I find that there exists a mean difference of magnitude of 0·15 in the magnitude of a single star. The mean difference between my magnitudes and those given in the *Durchmusterung* is 0·06 mag. These two catalogues, therefore, notwithstanding many individual discordances, may, in the average and on the whole, be regarded as in substantial agreement.

It will be remarked in reference to the above list, that it comprises stars of all magnitudes, though principally stars fainter than the third. They are scattered over all parts of the sky. They comprise about four per cent. of the whole number of stars compared. Each of them has been purposely re-observed at Oxford. But it must not be overlooked that the discordances are in reality between *four* fallible measures.

The result of our labours at Oxford is now open to scientific scrutiny. Inasmuch as this *Uranometria* is the first complete and

systematic research of the kind, undertaken photometrically by a European astronomer, it can scarcely fail to possess some historical relation. If, as I hope and anticipate, its general usefulness and accuracy shall be acknowledged, I trust it will not be forgotten that a very considerable share of both is due to the intelligent, unremitting, and scrupulous attention of the two assistants, Mr. W. E. Plummer, F.R.A.S., and Mr. C. A. Jenkins, F.R.A.S., by whom the necessary instrumental measurements have been made; in the aggregate they exceed seventy thousand.

Photometric Observations of the Nova in the Andromeda Nebula, made at the Oxford University Observatory. By Prof. C. Pritchard, D.D., F.R.S.

The following observations were taken for measuring the brightness of the new star in the *Andromeda* nebula. It was not observed at Oxford till Sept. 7, when its brightness was compared with that of μ and ν *Andromeda*, resulting in 8·25 mag. for the *Nova*. The star then rapidly declined in lustre until about the end of September, when it approached closely to the tenth magnitude. Since that time its brightness has faded so nearly to that of the nebula, that it is no longer measurable by the Photometer. Even during the latter part of the observations there has been very considerable difficulty in observing with exactness the magnitude of this star, on account of the brightness of the nebula in the background, which closely approaches that of the *Nova* in that portion of the nebula, near to which the star is situated. The image of that part of the nebula which appears in the photometric field, small as it is, and not exceeding a circle 25″ in diameter, nevertheless occupies a small *area* on the wedge, varying minutely in thickness, so that when the star is near the point of extinction some trace of an unextinguished light from the nebula is faintly visible.

From some cause or other, possibly connected with what has just been mentioned, the behaviour of the star in the nebula, as it approached extinction on the wedge, *even* in the earlier observations, was somewhat different from that of an ordinary star. It did not resemble the perfect point-like appearance which other stars present when near to extinction. In the large Refractor, however, no perceptible difference was observed between the *Nova* and other stars of similar brightness.

The following table contains an account of all the observations taken to fix the brightness of the *Nova* :

Date of Obs. 1885.	Magnitude of Nova when compared With *Polaris.*	With *μ Androm.*	With *ν Androm.*	With *R.* 204	Adopted Mean Mag. of Nova.
Sept. 7 (*a*)	—	8·16	8·34	—	8·25
9 (*b*)	8·44	8·51	8 50	—	8·48
11 (*c*)	9·19	9·20	—	9·19	9·19
13	—	9·08	—	9·01	9·05
18 (*d*)	—	9·44	—	9·23	9 34
21 (*e*)	9·89	9·92	—	9·70	9·84
21	10·07	10·09	—	9·96	10·03
24 (*f*)	9·63	9·77	—	9·57	9·66
25 (*g*)	9·81	9·95	—	9·80	9·85
26	9·66	9·68	—	9·80	9·71
30	9·65	9·72	—	9·71	9·69
Oct. 1 (*h*)	9·64	9·71	—	9·79	9·71
3	9·94	9·76	—	9·93	9·88
5	10·02	10·02	—	9·90	9·98
7	10·06	10·16	—	9·97	10·05
12	9·60	9·93	—	9·89	9 81
16 (*i*)	9·97	9·89	—	10·02	9·96

Notes.

(*a*), (*h*) Partially fine night; sky hazy.
(*b*) Drifting cloud. Definition not good. (*c*) Definition bad.
(*d*) Sky very hazy; drifting fog and cloud.
(*e*) Sky variable and foggy. Observation unsatisfactory.
(*f*) (*g*) Moon nearly full; definition bad. (*i*) Sky foggy.

Oxford University Observatory:
1885, *November* 12.

Observations of the Spectrum of the New Star in the Great Nebula in Andromeda, made at the Royal Observatory, Greenwich. By E. W. Maunder.

The spectrum of this object was observed with one or other of the spectroscopes of the Royal Observatory on the evenings of September 4, 11, 15, and 30. On the first occasion, when the half-prism spectroscope was used, both in the direct position, and reversed in order to give greater purity, the star gave a perfectly continuous spectrum, in which no lines either bright or dark could be detected. The red, orange, and violet were very faint or altogether wanting, the spectrum being traceable from about D to F, but being scarcely discernible beyond those limits. The spectrum of the star resembled that of the nebula precisely, except of course that it was brighter, and, probably in

consequence of this greater brightness, was traceable a little further in both directions.

On the evening of September 11 the single-prism spectroscope was employed, and the lower dispersion of this instrument proved more suitable for the examination of so difficult an object. The spectrum of the star was now traced from about λ 6600 to λ 4300; it was very faint in the red and orange, and began to brighten at a definite point, either D or close to it. Then followed a space relatively very bright, the centre of which was not far from E, but the brightest part of which was further towards the red, at a point for which two readings were obtained, viz. λ 5457 and λ 5508, mean λ 5482, and where at times the brightening appeared so definite as to suggest the presence of a bright line. The same general region was also much the brightest in the region of the nebula. The spectrum of the star declined rapidly in brightness beyond F; practically, it might be considered as confined between the two lines, D and F, the outer portions of the spectrum were so much fainter than the central district. From time to time bright lines were suspected in this district, the brightest being the line already mentioned, a second being measured as at λ 5327. The region of the *b* lines was specially examined, and also the neighbourhoods of both D and F, but no bright lines were seen in either locality.

The spectrum of the star was examined with a small prism held behind the eye-piece, on September 15, and the presence of the two bright lines was again suspected. And again on September 30 they were more satisfactorily observed, although the star had then lost much of its brightness, and its spectrum was but little brighter than that of the nucleus of the nebula. A third line was also suspected about as far beyond the magnesium line λ 5527 towards the red, as the brightest of the three bright lines, viz. that at λ 5482, was towards the blue. This would give its position as λ 5575. It could not be decided whether the lines were brighter than on September 11. They were recognised more easily than on that occasion, but, on the one hand, it was now known where they should be looked for, and on the other, the instrument now employed (the half-prism spectroscope in the reversed position) was the same as that used on September 4, when no trace of a bright line could be perceived. It was believed that the brightest line, that of λ 5482, could be traced over or near the nucleus of the nebula, but with so feeble a spectrum it was most difficult to make perfectly sure. The slit also was narrow, and it was found most difficult to keep either star or nebula upon it, their spectra being so faint that they were continually being lost.

On September 11 the spectra of two neighbouring stars were examined with a view to ascertaining whether the faintness of the extreme portions of the spectra of the star and nebula was due to either the spectroscope, the observer's eye, or the general feebleness of the light to be examined, or indicated a real deficiency in

the objects themselves of those kinds of light. The following rough settings were obtained for the limits of visibility of the spectra of two neighbouring stars, the new star and the nebula. The stars examined were Arg. Zone + 38°, Nos. 90 and 88.

Object.	Mag.	Limit towards the Red. Reading. r.	Limit towards the Red. Wave length tenth metres.	Limit towards the Violet. Reading. r.	Limit towards the Violet. Wave length tenth metres.
Arg. Z. + 38° No. 90	5·5	5·0	7380	85·0	3948
Arg. Z. + 38° No. 88	8 0	10·0	6808	76 0	4095
Nova	8·3	12·0	6615	64·0	4319
Nebula	—	17·0	6196	62·0	4363

It will be understood that the positions obtained are but very rough, as there was no definite point to be measured in any case; the micrometer, indeed, was only read to the nearest whole revolution.

The spectrum of the *Nova* was traceable a little further in both directions than that of the nebula. Towards the violet this seemed entirely due to its greater brightness, but towards the red the difference was greater than could fairly be explained upon this ground. The spectrum of the *Nova* seemed slightly brighter than that of No. 88 in the central district from D to F, but was decidedly feebler in the red and violet regions. The *Nova* was estimated as being three-tenths of a magnitude fainter than No. 88.

The colour of the star appeared to be about that of the D lines, and so far as could be judged it did not vary in tint from night to night, although it grew steadily less intense. On September 30, the last night of observation, a slight orange flush was still distinguished.

Its magnitude was roughly estimated as follows:—September 4, 8·0; September 11, 8·3; September 18, 9·2; September 21, 9·6; September 30, much fainter, and not greatly brighter than D'Arrest's star near it, or the nucleus of the nebula. The *Nova* was examined on two nights, September 18 and 21, to see if any disc could be detected. Both nights were foggy, and the nebula was all but extinguished. On September 21, whilst M. 31 was all but invisible, M. 32 was easily seen. The latter was therefore decidedly the brighter of the two. The *Nova* was perfectly sharply defined and free from fuzziness on both occasions. On September 18, with power 220, "the faintest suspicion of a larger disc than a star should show," was recorded. On September 21 "it bore every power up to and including one of 500, quite as well as the neighbouring stars. It was distinctly and sharply stellar in appearance, nor could anything be detected which could reasonably be termed a disc."

The observations were all made with the South-East Equatorial of 12·8 inches aperture and 17 feet 10 inches focal length.

Royal Observatory, Greenwich:
1885, *November* 12.

The Outburst in Andromeda. By Rev. S. J. Perry.

The *Nova* in *Andromeda* has been observed at Stonyhurst on every favourable occasion from September 13 to November 8. On September 13 the spectrum was found to be continuous, but the red end was absent, and there was a decided maximum in the green. A bright band in the green was suspected but not clearly seen. The spectroscope was carefully focussed on the lines in the spectrum of β *Andromedæ*, which were well seen, before being turned on the nebula of *Andromedæ*. On October 9 the spectrum was still brightest in the green.

The brilliancy of the *Nova* decreased at first very rapidly, but at present, although it is still very decidedly stellar, as is made evident by increase of power, there is no great change from day to day, the magnitude remaining at about the eleventh. With a low power the nucleus alone is visible, but with powers of from 200 to 300 the *Nova* still stands out very prominently, and is undoubtedly more brilliant than the nucleus.

Stonyhurst Observatory:
1885, *November* 11.

Note on Mr. Chambers's suspected New Variable in Corona Borealis. By Rev. T. E. Espin.

The star observed by Mr. Chambers is the variable star No. 109 of Gore's catalogue of known variable stars. It is there termed *V Coronæ*. The variation was discovered in 1878 by Dunér.

The star was observed by me on the night of June 9, 1885, with 9-inch Equatorial Reflector, during the reobservation of Birmingham's red stars, and I was as much surprised as Mr. Chambers at finding so finely coloured a star where Birmingham and Ball had previously found none. I extract from my note-book the observation of it.

"This star must be variable; Ball and Birmingham (4 obs.) did not see it. It was at once seen to-night, and identified as DM+40°·2929. Colour fine red. There is a star 8·0 DM+40 2928 6′·3 N. of it. The neighbouring star S, DM+39°·2920 is evidently underrated by Argelander, who gives it 9·4. It is now nearly equal to DM+39·2923, whose magnitude, according to Argelander, is 8·9. The red star is about 9·0 mag."

Dunér's discovery of its variation was announced in the *Astr. Nach.* No. 2227.

High Street, Wolsingham, Darlington:
1885, *November* 7.

Notes on the Total Solar Eclipse of September 9, 1885, viewed at the Terrace, Wellington, New Zealand. By Charles Rous Marten, F.R.G.S., F.R.Met.Soc.

(*Communicated by Prof. Adams.*)

The following are simply what they profess to be—"Notes"—and do not claim to be in any sense complete or exhaustive observations. Such elaborate and extensive preparations had been made for the observation of the eclipse by the regular official authorities, that I assumed that these would furnish all the results ordinarily desired, and accordingly I devoted my own attention rather to certain details respecting which I felt personally interested. Finding, however, that the official observations were in a large degree marred by unfavourable weather, I send, for what they may be worth, such general notes as I made, having been fortunate in enjoying a perfect view of the phenomenon. The particular details to which, as mentioned above, I addressed my especial attention, I have not time now to deal with, but I may do so at a future date.

The day of the eclipse was ushered in by most unpromising conditions of weather—a strong southerly gale blew from seaward, bringing dense masses of cloud and a very low temperature.

Westward the sky was fairly clear, but eastward the cloud canopy was very heavy. The Sun was not once visible until 7.4 A.M., but from that time forward it was never seriously obstructed by clouds. My position was in my front garden, at an elevation of about 100 feet above the level of the bay; my apparatus was of the simplest kind. An exceptionally good binocular field-glass, darkened glasses for use before and after totality, an excellent chronograph, self-registering thermometers by Casella.

At 7.4 A.M. the solar disc, then partially eclipsed, showed itself through a rift in the clouds. The clouds then cleared off, excepting on the horizon, and an absolutely perfect view was obtained thenceforward to the conclusion. No noteworthy diminution of light could be discerned by the mere vision until fully two-thirds of the solar disc had become covered, but from the time the first decrease in illumination was noticeable, the light faded very swiftly. The sunlight in New Zealand is usually exceedingly brilliant, far more so than in England, and quite as vivid as in most tropical countries. I observed the difference on the one hand, and the similarity on the other, in my recent visits to England and Brazil.

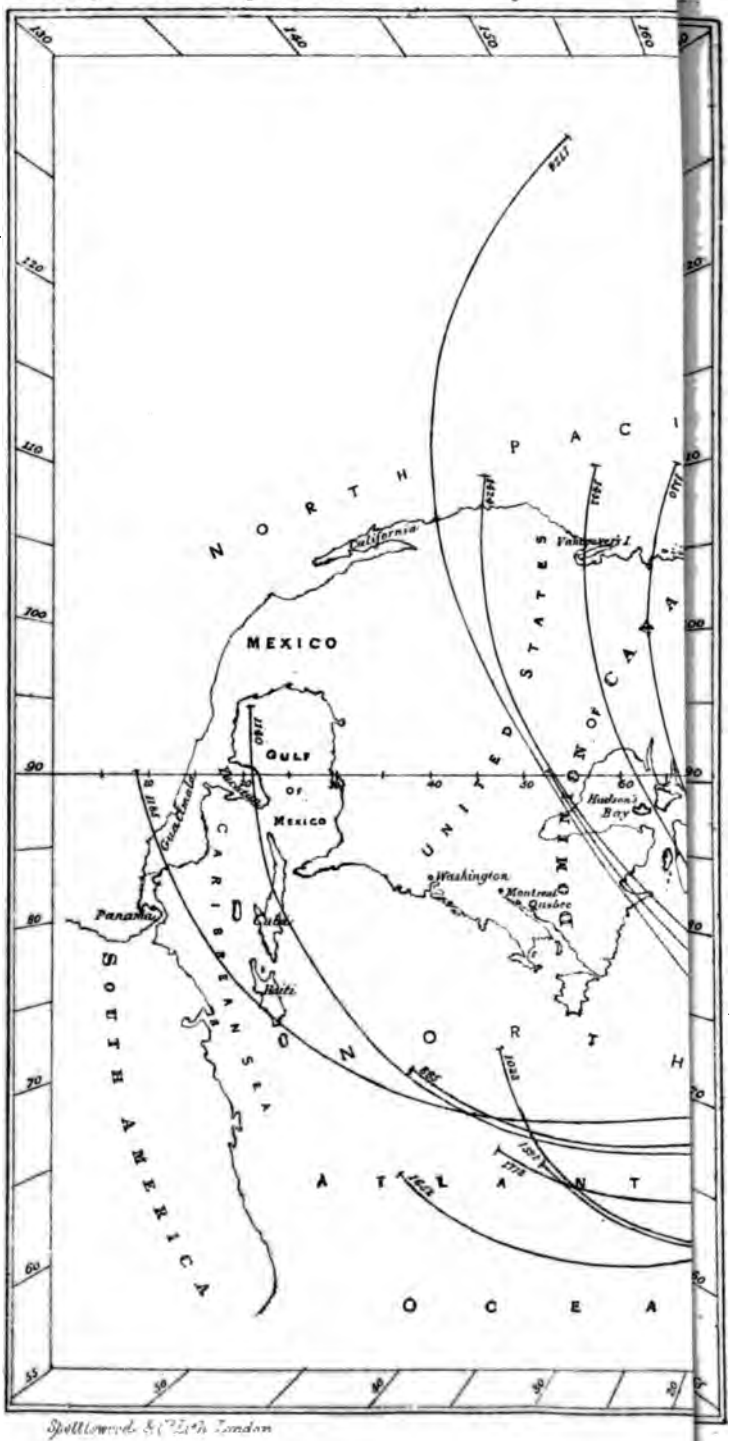
As totality approached, the effects of light and shade on terrestrial objects were very weird and striking. I may add that they differed materially in intensity from those I have observed in two former eclipses. There was a curious mixture of purple and green and bronze in the hues pervading the hills, while the blue sky deepened into iron grey and then to a leaden

tint, the waters of the bay looking like ink. The white and light coloured had a strangely wan, pallid look. I mention these points because I attribute the effects to the same cause that produces the fore-glow and after-glow which have preceded sunrise and followed sunset so frequently during the last two years. I shall have occasion to return to this matter.

Shortly before totality, I should say fifteen to twenty seconds—but I was unable to take the time with precision, being otherwise occupied—the entire disc of the Moon became suddenly visible against the white background of the solar corona, and then the approach of the dark shadow of totality could be plainly seen as it moved swiftly across the landscape. An instant before totality the solar light was concentrated into one intensely brilliant point, strongly resembling the light of the electric arc, and then came the complete obscuration. The darkness was not so great as I had anticipated, being about equal to that of a moonlight night in the Moon's first quarter. I attribute this partly to the amount of light reflected from the bulky masses of cumulous cloud which hung around the horizon, and partly to the illuminating influence of the "glow" which surrounded the eclipsed Sun like a huge rosy-mauve halo. A watch face could be easily read at the darkest period.

The corona presented a splendid spectacle surrounding the jet-black lunar disc. It was deeply serrated, or rather "rayed," pearly white with rays streaming out to a distance of fully two lunar diameters, and in the case of one on the upper left quadrant, more. Another long ray proceeded from the lower right quadrant, and there was an apparent equatorial protuberance. The whole appearance of the corona almost exactly resembled that of the Aurora Australis as I have often observed it at my former observatory in the extreme south of New Zealand, then the most southern observatory in the world. There was also a seeming unsteadiness at times noticeable in the auroral light, and a distinctly varying degree of luminosity in the coronal rays, while near the lunar edge there was, on the advancing side just after totality, and on the retreating side just before the reappearance of the Sun, a yellowish tinge, the rayed structure was very marked at the moment of absolute centrality.

The red prominences were visible in remarkable brilliancy to a far greater extent than I have ever seen described in accounts of other total eclipses. To describe their extent very roughly, I should say that, taking a clock face and its minutes as the gauge, one serrated series of prominences on the upper limb of the Sun, resembling a mountain range of red flames, extended from $0^h\,54^m$ to $0^h\,3^m$ in full brilliancy, and that red traces extended on the left hand to $0^h\,52^m$, and on the right to $0^h\,4^m$. Other large but narrow red prominences were at $0^h\,39^m$ and at $0^h\,20^m$. I fancied I saw a fourth momentarily at $0^h\,30^m$. These "times" will be distinctly understood to indicate merely the *positions*—


NORTH PACIFIC OCEAN
MEXICO
GULF OF MEXICO
CARIBBEAN SEA
UNITED STATES OF AMERICA
NORTH ATLANTIC OCEAN
SOUTH AMERICA
California
Panama
Cuba
Haiti
Washington
Montreal
Quebec
Hudson's Bay
Spottiswoode & Co. New-Street Square London

regarding the Sun's disc as a clock-face—and as I have explained at the outset, I cannot pretend to any great exactness in fixing them, as much of my attention was otherwise engaged. The prominences were very rich in colour and seemed, like the corona, to vary in intensity. They also seemed to vary in depth of hue, ranging from pink or rose to scarlet and almost to crimson. They had a markedly transparent appearance, like a light shining through coloured glass. I found I could see them quite plainly with my naked eye, after once having ascertained their position by means of the glass.

The "glow" seen before sunrise and after sunset now appeared in great beauty and richness of tint, surrounding the eclipsed Sun. The pink, rose, and mauve hues, the latter deepening to violet, and then fading to lavender, were very fine. The glow had extended round the dark body of the Moon as it advanced over the Sun, and similarly it preceded the Moon as it passed off the Sun's face. None could be seen on the uneclipsed side of the Sun. The exact time, carefully taken by chronograph, which elapsed between the final disappearance of the last sparkle of solar light on the right hand and the reappearance of the first sparkle on the left was 1 min. 32·9 secs.

The temperature, which was 49°·1 at sunrise, gradually fell during the eclipse, and finally receded to 43°·6, a fall of 5°·5. This was a smaller difference than I had expected. I imagine the smallness was due to the strong gale blowing, which must have tended to equalise temperatures. I fancy also that the disturbed state of the atmosphere may possibly be responsible for the seeming variation and unsteadiness of the coronal light and red flames.

Jupiter was very clearly visible during totality, also several stars, but the time was too short to allow of my recording particulars in addition to my other notes.

I forward these rough notes, *quantum valeant*, and can only express my regret that I had not, in anticipation of possible failure in the case of the official observations, made arrangements for observing the eclipse fully, and having telescopic, spectroscopic, and photographic records taken. However, if my very crude notes should prove of any service I shall be more than repaid my trouble in writing them.

The Terrace, Wellington:
1885, *September* 9.

Total Solar Eclipses A.D. 878 *to* 1724. By Joseph Maguire.

In the May number of the *Monthly Notices* parts of the central and limiting lines of these thirteen eclipses are shown on a map of the British Isles.

The map sent herewith, and to which this communication

refers, shows the completion of the central lines from beginning to end; and perhaps its publication in the *Monthly Notices* may not be considered undesirable.

The Greenwich Mean Times of beginning and ending, with the longitudes and latitudes in each case, are given as follows:—

Date.		h m	Beginning. Long. W. ° ′	Beginning. Lat. N. ° ′	Ending. Long. E. ° ′	Ending. Lat. N. ° ′
878	Oct. 29	0 37·5	42 8	73 0		
,,	,, ,,	1 52			36 51	53 41
885	June 15	20 54·5	58 24	29 50		
,,	,, ,,	23 34·6			117 37	40 24
1023	Jan. 23	22 57·6	55 52	38 26		
,,	,, 24	0 34·7			16 24	71 6
1133	Aug. 1	22 36·5	90 42	53 11		
,,	,, 2	1 29			71 44	10 2
1140	Mar. 20	0 27	96 19	20 38		
,,	,, ,,	3 8·4			48 14	56 16
1185	Apr. 30	23 44·6	90 6	8 56		
,,	May 1	2 39·8			70 30	50 20
1330	July 16	2 2·5	144 4	49 53		
,,	,, ,,	4 31·8			38 14	37 28
1424	June 26	1 10·2	125 4·6	36 53		
,,	,, ,,	3 49·6			51 12	36 21
1433	June 17	1 26·7	135 26	43 57		
,,	,, ,,	4 1·7			44 48	30 46
1598	Mar. 6	21 20·7	42 35	34 5		
,,	,, ,,	22 57·1			3 54	84 10
1652	Apr. 7	21 16·2	51 33	22 27		
,,	,, ,,	23 29·4			130 6	76 33
1715	May 2	20 24·5	46 53	32 4		
,,	,, ,,	22 48·9			130 1	54 47
1724	May 22	3 42·7	152 6	14 21		
,,	,, ,,	6 37·8			11 51	45 31

Norwich:
1885, *September.*

Daylight Occultation of Aldebaran on July 9, 1885, observed at Forest Lodge, Maresfield. By Captain W. Noble.

Although the Moon's age was about 26·43 days, her bright limb, at moments of good definition, was seen sharp and clear against the sunlit sky. *Aldebaran*, too, was brilliant enough at intervals, but the undulation was at times very great indeed. Most unfortunately, one of these fits of "boiling" came on just as the Moon's limb was in contact with the star, so that the best estimation I could make of its disappearance was that it occurred on July 8, $23^h\ 25^m\ 17^s{\cdot}8 \pm$ Local Mean Time $= 23^h\ 25^m\ 0^s{\cdot}00$ G.M.T. I made no attempt to observe the reappearance. Power employed, 74 on my 4·2-inch Ross Equatoreal. Latitude of my observatory, 51° 0′ 56″·3 N.; longitude, 17·8 seconds E.

Forest Lodge, Maresfield, Uckfield:
1885, *July* 9.

Erratic Meteors. By B. J. Hopkins.

As is well known to observers of meteors, the apparent paths of those bodies, as seen by us projected upon the celestial vault, are generally in the form of a curve, but sometimes they appear to travel in straight lines, while a comparative few have no appreciable path, being seen only as points of light, which are no sooner observed than they are gone.

There is, however, a class of meteors that I have occasionally observed, though never found described in the text-books, which differs from those usually seen in that they travel in a zigzag or wavy path; from which circumstance and the rarity of their appearance I propose designating them "erratic" to distinguish them from ordinary meteors, which, it is perhaps needless for me to mention, they resemble in every other particular.

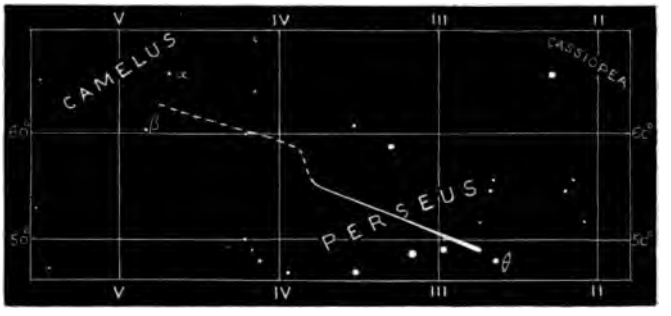
As I have said, these meteors are very rarely seen; I first observed one in the year 1879, and I have only noticed two since—one in 1881 and the other on September 9 of the present year. Details of these meteors I give in the following extracts from my note-books, which, together with the charts showing their course among the stars and the form of their paths, will make clear what I mean by erratic meteors.

Extracts from Note-books.

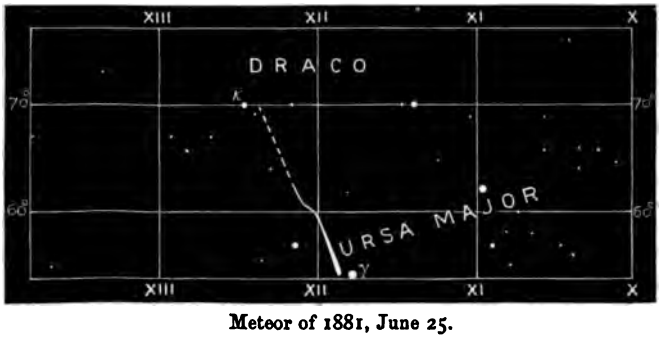
1879, Oct. 20.—$10^h\ 49^m$ G.M.T. Observed a bright yellow meteor, which described a zigzag path with two bends, as shown in diagram. Appeared between α and β *Cameli*, disappeared near θ *Persei*.

1881, June 25.—$12^h\ 4^m$ G.M.T. Observed a bright white meteor = 4. Appeared just south of κ *Draconis*, disappeared near γ *Ursæ Majoris*, after pursuing a wavy path.

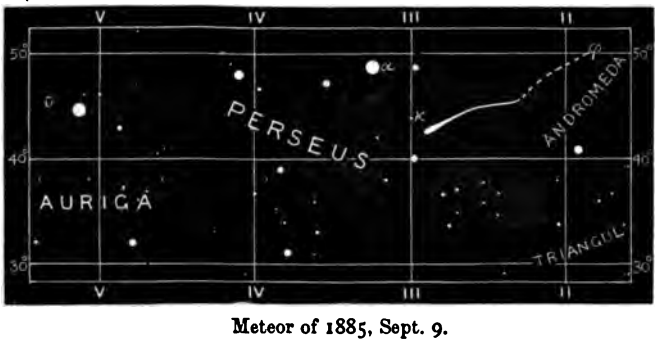
1885, Sept. 9.—10^h 15^m G.M.T. Bright orange-coloured meteor=1. Appeared near ϕ *Persei*, disappearing just north of κ *Persei*, after describing a zigzag path with three bends.



Meteor of 1879, Oct. 20.



Meteor of 1881, June 25.



Meteor of 1885, Sept. 9.

For the sake of clearness, the scale being so small, the bends in the paths, as shown on the charts, are greatly exaggerated; in no case did a bend extend over more than 20 minutes of arc.

Forest Gate, Essex.

On the Application of a Nicol's Prism to Sextant Observations.

By Thomas Mackenzie.

(*Communicated by Capt. H. Toynbee.*)

I beg to submit to the consideration of the Royal Astronomical Society the application of the Nicol's prism to sextant observations made at sea, for up to the present moment I am unaware of a polariser having been employed with the sextant. My application of it is as follows. A Nicol's prism is inserted in the inverting telescope on the object-glass side of the diaphragm and close against it, and so placed that when the telescope is screwed home in its collar the polarising plane will be parallel to the plane of the sextant, and consequently perpendicular to the plane of the horizon when making observations. Now at sea observations for time are usually taken when the Sun has an altitude of between 30° and 40° in low latitudes, at which time there is a considerable glare on the horizon, rendering it very indistinct even when the coloured shades are used. In high latitudes, such as that of England, except in midsummer, there is always more or less horizon glare even at the Meridian altitude, so that the advantages of such an instrument would be more striking. The glare of light from the horizon is totally refracted out of the prism, and only the extraordinary ray transmitted to the eye, rendering the horizon comparatively dark and clearly defined, and free from the displacement which coloured shades wanting in parallelism of their faces always give.

I have now employed the instrument at sea during a voyage to the West Indies and South America, and it has fulfilled all I expected of it.

R.M.S. "Moselle," Southampton:
1885, August 13.

Ephemeris for Physical Observations of Mars, 1886.

By A. Marth.

Greenwich Noon.	Angle of Position of δ's axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Diameter.	ρ	Q	E	Log. Light ratio.
1885.	°	°	°	″	″	°	°	
Dec. 24	20·85	94·49	+ 23·52	8·30	0·76	292·58	35·32	9·2205
26	21·19	75·65	23·50	8·44	·77	292·53	35·05	·2351
28	21·50	56·83	23·47	8·58	·77	292·47	34·75	·2499
30	21·79	38·05	23·43	8·73	·76	292·40	34·42	·2650
1886.								
Jan. 1	22·07	19·31	+ 23·39	8·88	0·76	292·33	34·06	9·2804
3	22·33	0·60	23·35	9·04	·76	292·24	33·67	·2960
5	22·57	341·92	23·30	9·20	·75	292·14	33·24	·3118

Greenwich Noon.	Angle of Position of ♂'s axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Diameter.	ϕ	Q	E	Log. Light ratio.
1886.	°	°	°	″	″	°	°	
Jan. 7	22·79	323·28	23·25	9·36	·75	292·03	32·78	9·3278
9	22·98	304·69	23·20	9·53	·74	291·92	32·29	·3441
11	23·16	286·14	23·15	9·70	·73	291·79	31·76	·3605
13	23·32	267·63	23·10	9·88	·71	291·64	31·18	·3770
15	23·46	249·17	23·05	10·06	·70	291·48	30·57	·3937
17	23·57	230·75	22·99	10·24	·68	291·31	29·92	·4105
19	23·66	212·37	22·93	10·43	·66	291·13	29·22	·4274
21	23·72	194·05	22·87	10·61	·64	290·92	28·48	·4443
23	23·77	175·77	22·81	10·81	·62	290·69	27·70	·4612
25	23·79	157·55	22·76	11·00	·59	290·44	26·86	·4781
27	23·78	139·38	22·70	11·20	·57	290·17	25·98	·4949
29	23·75	121·27	22·65	11·39	·54	289·87	25·05	·5115
31	23·69	103·21	22·60	11·59	·50	289·53	24·07	·5280
Feb. 2	23·61	85·20	+22·55	11·79	0·47	289·16	23·03	9·5442
4	23·50	67·25	22·50	11·99	·43	288·74	21·95	·5601
6	23·36	49·36	22·46	12·18	·40	288·27	20·81	·5756
8	23·20	31·52	22·41	12·37	·36	287·73	19·62	·5907
10	23·01	13·74	22·37	12·55	·32	287·11	18·38	·6052
12	22·79	356·01	22·33	12·73	·28	286·39	17·09	·6191
14	22·55	338·33	22·29	12·90	·24	285·54	15·76	·6322
16	22·28	320·70	22·25	13·06	·20	284·52	14·39	·6446
18	21·98	303·12	22·21	13·22	·17	283·29	12·97	·6562
20	21·66	285·58	22·17	13·36	·13	281·72	11·52	·6668
22	21·32	268·08	22·14	13·49	·10	279·64	10·03	·6764
24	20·95	250·61	22·10	13·61	·07	277·0	8·54	·6850
26	20·57	233·18	22·07	13·71	·05	273·1	7·03	·6924
28	20·17	215·77	22·04	13·80	·03	268·1	5·54	·6986
Mar. 2	19·75	198·39	+22·00	13·87	0·02	256·9	4·14	9·7036
4	19·33	181·02	21·97	13·92	·01	237·5	2·97	·7073
6	18·89	163·65	21·94	13·95	·01	203·4	2·44	·7096
8	18·45	146·28	21·91	13·96	·01	168·7	2·93	·7106
10	18·01	128·91	21·89	13·95	·02	148·7	4·09	·7103
12	17·57	111·53	21·86	13·93	·03	138·2	5·50	·7087
14	17·13	94·13	21·84	13·89	·05	132·0	7·00	·7058
16	16·71	76·71	21·82	13·83	·08	128·0	8·54	·7016
18	16·29	59·25	21·80	13·75	·11	125·22	10·07	·6963
20	15·89	41·76	21·79	13·66	·14	123·13	11·59	·6948
22	15·51	24·24	21·78	13·56	·18	121·52	13·08	·6823

Greenwich Noon.	Angle of Position of ♂ axis.	Areographical Longit. of Centre of Disc.	Areographical Latit. of Centre of Disc.	Diameter.	ϱ	Q	E	Log. Light ratio.
1886	°	°	°	″	″	6	°	
Mar. 24	15 15	6·67	21·78	13·44	·22	120·22	14·54	9·6738
26	14·81	349·05	21·78	13·31	·26	119·16	15·97	·6643
28	14·50	331·39	21·79	13·17	·30	118·27	17 36	·6540
30	14·21	313·67	21·81	13·02	·34	117·51	18·71	·6429
Apr. 1	13 95	295·90	+21·83	12·86	0·39	116·85	20·01	9·6311
3	13·71	278·08	21·86	12·69	·43	116·28	21·26	·6187
5	13·51	260·20	21·90	12·52	·48	115·78	22·46	·6058
7	13·34	242·26	21·95	12·35	·52	115·35	23·61	·5924
9	13·20	224·26	22·00	12·17	·56	114·97	24·71	·5786
11	13·09	206·21	22·06	11·99	·60	114·63	25·76	·5645
13	13·01	187·10	22·13	11·81	·63	114·33	26·76	·5501
15	12·96	169·94	22·21	11·62	·67	114·07	27·71	·5356
17	12·95	151·72	22·29	11·44	·70	113·84	28·61	·5209
19	12·96	133·45	22·38	11·26	·73	113·64	29·47	·5061
21	13·00	115·13	22·48	11·08	·76	113·47	30·28	·4913
23	13·07	96·75	22·58	10·91	·78	113·32	31·04	·4764
25	13·17	78·33	22·69	10·73	·80	113·19	31·76	·4616
27	13·29	59·86	22·80	10·56	·82	113·08	32·44	·4469
29	13·44	41·34	22·92	10·39	·84	112·99	33·08	·4322
May 1	13·61	22·78	+23·04	10·22	0·86	112·91	33·69	9·4176
3	13·80	4·18	23·16	10·06	·87	112·85	34·25	·4032
5	14·02	345·53	23·29	9·90	·88	112·80	34·78	·3889
7	14·27	326·84	23·42	9·74	·89	112·77	35·27	·3748
9	14·53	308·11	23·55	9·59	·90	112·75	35·73	·3610
11	14·81	289·34	23·68	9·45	·91	112·74	36·15	·3473
13	15·11	270·54	23·81	9·30	·91	112·73	36·55	·3338
15	15·43	251·70	23·94	9 16	·92	112·74	36·91	·3206
17	15·77	232·82	24·08	9·02	·92	112·75	37·25	·3076
19	16·12	213·91	24·21	8·89	·92	112·77	37·56	·2948
21	16·49	194·98	24·34	8·76	·92	112·79	37·85	·2823
23	16·87	176·01	24·47	8·63	·92	112·81	38·11	·2700
25	17·27	157·01	24·59	8·51	·92	112·84	38·35	·2580
27	17·68	137·98	24·72	8·39	·92	112 88	38·57	·2462
29	18·10	118·93	24·84	8·27	·91	112·91	38·77	·2347
31	18·53	99·85	24·95	8·16	·91	112·95	38·94	·2234
June 2	18·97	80·74	+25·06	8·05	0 90	112·99	39·10	9·2123
4	19·42	61·61	25·17	7·95	·90	113·03	39·24	·2015
6	19·88	42·46	25·27	7·84	·89	113·07	39·36	·1910

Greenwich Noon.	Angle of Position of ♂'s axis.	Areographical Longit. of centre of Disc.	Areographical Latit. of centre of Disc.	Diameter.	q	Q	E	Log. Light ratio.
1886.	°	°	°	″	″	°	°	
June 8	20·35	23·28	25·36	7·74	·88	113·11	39·46	9·1807
10	20·83	4·08	25·45	7·64	·87	113·15	39·55	·1706
12	21·31	344·85	25·53	7·55	·87	113·19	39·62	·1608
14	21·80	325·61	25·60	7·46	·86	113·23	39·67	·1512
16	22·29	306·35	25·67	7·37	·85	113·26	39·71	·1419
18	22·79	287·07	25·73	7·28	·84	113·29	39·74	·1328
20	23·29	267·77	25·78	7·20	·83	113·32	39·76	·1239
22	23·79	248·46	25·82	7·12	·82	113·34	39·77	·1153
24	24·30	229·13	25·85	7·04	·81	113·36	39·76	·1068
26	24·81	209·78	25·87	6·96	·80	113·38	39·74	·0986
28	25·32	190·42	25·88	6·89	·79	113·39	39·71	·0906
30	25·82	171·04	+25·89	6·81	0·78	113·39	39·67	9·0828

Q denotes the position-angle, and q the amount of the greatest defect of illumination; E the areocentric-angle between Earth and Sun. The last column gives the logarithm of the ratio of the apparent brightness of *Mars* to that at mean opposition, computed upon the supposition that the diminution of brightness due to the phase depends simply on the proportion of the unilluminated portion to the whole of the disc. The maximum value of the logarithm of this light-ratio during the last four oppositions has been

1877	Sept. 3	0·3696	1881	Dec. 20	9·8442
1879	Nov. 3	0·1021	1884	Jan. 30	9·7163

while that of the coming opposition is

1886 Mar. 6 9·7106

The data of the ephemeris are to be interpolated directly for the times for which they are required, the equation of light having already been taken into account. The difference of successive values of the longitude of the centre of the disc amounts to one rotation and some 340 degrees, so that, for instance, the difference from December 24 to 26 is 701°·16, which must be borne in mind in interpolating.

As the observations of *Mars* made during the last two oppositions do not seem to have contributed anything further towards a better determination of the position of the planet's equator, I have now made the slight change from the values of the node N and inclination J in reference to the plane of the Earth's equator of 1880·0

$$N = 47°{\cdot}945 \qquad J = 36°{\cdot}260.$$

which I had adopted in the ephemeris for 1879 (vide vol. xxxix. p. 473) to those determined by Schiaparelli from his own measurements of 1877 and 1879

$$N = 48^\circ{\cdot}130 \qquad J = 36^\circ{\cdot}382.$$

The Zero-Meridian has also been shifted in order that it may pass, as nearly as Schiaparelli's measurements will permit, through the point of the tongue of the forked bay of Dawes or through Schiaparelli's Fastigium Aryn. The correction applied is $+1^\circ{\cdot}32$ for the beginning of 1880.

I have, further, made the slight change from the daily rate of rotation $350^\circ{\cdot}8922$, which I had used since 1864, to the rate $350^\circ{\cdot}89214$, which I have deduced from what appear to me by far the best old observations available for the purpose—namely, those made by Maraldi in 1704 and the corresponding ones of Schiaparelli made in 1879, as already mentioned in vol. xliii. p. 493. The daily rate $350^\circ{\cdot}89214$ is the tropical one in reference to the equator; the sidereal rate is $0^\circ{\cdot}0000384$ greater, and the corresponding period of the sidereal rotation of *Mars* is $24^h\ 37^m\ 22^s{\cdot}63$, only $0^s{\cdot}01$ greater than Kaiser's value of 1864. In another communication I shall give, for the times assigned to the older sketches, the areographical longitudes and latitudes of the centre of the disc according to the system adopted in the present ephemeris.

It is desirable that the question should be settled how far the variations in the aspect of the dark markings on *Mars* are due to the relative position of the Sun and the Earth, and especially what changes take place in the aspect of a marking, when, in the course of rotation, it reaches or leaves the vicinity of the point where Sun and Earth have the same areocentric zenith distances, but opposite azimuths. Though this point may be found from the data of the ephemeris, as it is in position-angle $Q+180^\circ$ and at the areocentric angular distance $\frac{1}{2}E$ from the apparent centre of the disc, or geocentrically at the distance $\sin \frac{1}{2}E$ of the semi-diameter, observers may perhaps be more readily induced to watch their opportunities, if they can easily get the areographical longitude ω' and latitude β' of the point. I give, therefore, at intervals of eight days, the difference $\omega' - \omega_0$ of the longitude of the point in question from that of the central meridian ω_0, and also the latitude β'. In the last column I have added the areocentric longitude of the Sun reckoned in the plane of the orbit from the ascending node of the orbit on the planet's equator, or analogous to the reckoning of the Sun's geocentric longitude in the ecliptic, so that the actual season on *Mars* corresponds to the terrestrial season when the Sun's geocentric longitude is $= \odot'$.

	$\omega'-\omega_0$	β'	$\odot'$		$\omega'-\omega_0$	β'	$\odot'$
1885.	°	°	°	1886.	°	°	°
Dec. 24	−19·1	+21·8	47·6	Mar. 30	+ 9·9	+23·7	89·7
1886.							
Jan. 1	−18·4	22·2	51·1	April 7	12·6	23·9	93·3
9	−17·5	22·5	54·6	15	14·9	24·2	96·8
17	−16·2	22·7	58·2	23	16·8	24·5	100·4
25	−14·6	22·9	61·7	May 1	18·3	24·7	104·1
Feb. 2	−12·5	23·0	65·1	9	19·5	24·9	107·7
10	− 9·9	23·0	68·6	17	20·5	25·0	111·4
18	− 7·0	23·0	72·1	25	21·1	25·0	115·1
26	− 3·6	23·1	75·6	June 2	21·6	24·9	118·9
Mar. 6	− 0·1	23·2	79·1	10	21·8	24·6	122·7
14	+ 3·5	23·3	82·6	18	21·9	24·3	126·5
22	+ 6·8	+23·4	86·2	26	+21·8	+23·8	130·4

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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EDWIN DUNKIN, F.R.S., President, in the Chair.

James Hunter, F.R.C.S.E., F.R.P.S., Craigmillar Park, Edinburgh;

Walter Claude Johnson, Mem. Inst. C.E., 8 Vanbrugh Park, Blackheath, S.E.;

Richard Wilding, Sunny Bank, Victoria Road, Fulwood, Preston,

were balloted for and duly elected Fellows of the Society.

On the Term of Long Period due to Mars in the Expression for the Longitude of the Moon. By Edmund Neison.

In the last volume of the *Memoirs* (vol. xlviii., Part II. p. 419), there is a paper by M. Gogou, containing a calculation of the value of the term of long period in the expression for the longitude of the Moon, arising from the disturbing action of *Mars*, together with a lengthy criticism of my own merely provisional calculations published in the *Monthly Notices* for November 1877 (vol. xxxviii. pp. 49–53).

M. Gogou finds a result differing much from mine, and this difference he considers due to three things:

I. Because I employ strictly undisturbed elliptic coordinates of the Moon instead of coordinates partially modified by the action of the Sun.

II. Because there are errors in the expression assigned by me to the disturbing function.

III. Because I have omitted a number of small terms which have been retained by him.

Practically the whole *Memoir* is devoted to supplying these deficiencies, so some comment on my part seems called for.

It should be borne in mind that the calculation so elaborately criticised by M. Gogou in his eighteen pages of the *Memoirs* was a mere first provisional calculation occupying just three pages of the *Notices*, a calculation stated at the time to be a mere provisional approximation needing revision and extension, as well as the inclusion of the higher powers of the disturbing forces.

My reply to M. Gogou's criticism is short and direct.

I. I employed the strictly undisturbed values of the elliptic coordinates of the Moon, because, as expressly stated, my calculation was confined to the part of the co-efficient depending on the first power of the disturbing forces.

By introducing a few terms nominally independent of m, M. Gogou has vitiated the accuracy of his results, for these terms, though independent, by a mere convention, of m, do all the same depend on the disturbing power of the Sun; and if the effects of the disturbing action of the Sun is to be introduced at all, it must be introduced throughout and not only in part, and must include the terms explicitly depending on m as well as the terms which merely implicitly depend on m.

II. M. Gogou shows that there are errors in the expression assigned by me to the disturbing function on page 52 of my original note. This is true; in two places a is printed for a^2, and in one case a is printed for $2a$. But a glance at the previous steps ought to have shown M. Gogou that these are purely printer's errors of not the slightest importance, as they do not exist in the calculations themselves. The very symmetry of the previous expansions might have shown this to M. Gogou, and thus saved him compiling an elaborate memoir to rectify some printer's omissions.

III. The reason why I omitted the terms forming M. Gogou's expression R., is expressly stated in my original note, because they were so small as to be insensible (p. 51, lines 10–12). All that M. Gogou has done has been to show by an elaborate calculation that I am perfectly correct—they are absolutely insensible. I did not deem a calculation necessary, as the result was so obvious.

It is true, that according to M. Gogou, the more important portion of the co-efficient, that calculated by me, yields results no larger than this other. But even were this really the case, it does not show, as M. Gogou seems to think, that I ought to have elaborately calculated both, but merely that I need not have calculated either.

It is not too much to say that nine-tenths of this memoir of M. Gogou's is devoted to the elaborate calculation of small terms which could not possibly be of the smallest importance, being, as

already pointed out by me, so small as to be completely insensible. And all that this part of M. Gogou's memoir does is to prove the correctness of this statement of mine. The remainder consist merely of a somewhat more detailed expression for the terms calculated by me, but with this difference, as pointed out in my note in the *Monthly Notices* for March 1885 (vol. xlv. pp. 326–328), that my calculations are more complete than those of M. Gogou. This note in the *Monthly Notices* for March, deals with the only real issue between us, and the entire memoir of M. Gogou is utterly beside the question, being devoted to the elaborate calculation of a mass of small terms, which we both agree in finding completely insensible.

My own memoir on this subject, like all the rest of my scientific work, was brought to a complete standstill by long severe illness throughout the entire summer; and though slowly recovering, I fear their publication will all be seriously delayed, as it will be some time yet ere I can return to the mathematical work.

The Observatory, Natal:
1885, *Nov.* 9.

Comparison of Groombridge's and Struve's Right Ascensions of Close Circumpolar Stars. By Truman Henry Safford.

Groombridge's Catalogue of Circumpolar Stars is so important, and in many respects excellent, that its positions ought to be improved as far as possible. The attempt has been made to do this by the application of systematic corrections; but those in Right Ascension are hardly well enough known for the region immediately about the North Pole.

The correction usually employed is Argelander's

$$+0^{s}.06 + 0^{\circ}.12 \tan \delta.$$

which is derived from the previous investigations of Struve and Fedorenko, combined with his own.

Struve's hypothesis is that Groombridge's meridian mark was about 3″ in error; but the comparisons which I give in the present paper will show that this may not be altogether certain, at least for the earlier period (1806–1809), when Groombridge was especially observing the closer polars.

Within 10° of the Pole there are few stars with which comparison has been made between Groombridge and later observers. In order to fill this gap, I have compared his catalogue with the Dorpat Right Ascensions observed by W. Struve in 1814 and 1815. In this I have employed only Struve's Catalogus I., which contains the closer stars, and have confined myself to the region north of +70°. The results are as follows:—

ZONE +86° TO +90°.

No. Groombridge.	Polar Distance.	Δα Struve-Groombridge.	Δα cos δ.
	°	s	s
144	2·0	− 1·82	−0·06
235	1·7	+ 0·40	+0·01
642	4·0	− 1·14	−0·08
1119	0·9	−12·05	−0·20
1141	2·7	− 3·73	−0·18
1850	3·4	+ 1·09	+0·06
1871	2·5	− 0·67	−0·03
1884	1·3	− 0·93	−0·02
2006	1·4	+ 3·29	+0·08
2065	1·5	+11·8	+0·31
2099	3·4	+ 3·71	+0·22
2210	3·3	+ 3·88	+0·22
2283	2·1	+ 1·63	+0·06
2628	3·4	+ 0·07	0·00
2667	3·1	+ 0·45	+0·02
3308	1·3	+ 1·83	+0·04
3548	3·7	+ 0·88	+0·06
4101	3·7	− 0·35	−0·02

ZONE +83° TO +86°.

No. Groombridge.	Polar Distance.	Δα Struve-Groombridge.	Δα cos δ.
	°	s	s
67	4·7	+0·79	+0·06
177	4·8	+0·20	+0·02
595	5·8	+2·49	+0·25
750	5·0	+0·47	+0·04
766	6·7	+0·44	+0·05
944	4·9	−0·83	−0·07
956	4·8	+2·63	+0·22
1359	5·4	−5·56	−0·53
1418	4·3	−5·72	−0·43
1620	4·8	+0·47	+0·04
1633	6·5	−0·33	−0·04
1889	5·3	+2·91	+0·27
1937	5·6	+1·15	+0·11
1940	5·6	+1·76	+0·17
2007	4·3	+1·12	+0·09

No. Groombridge.	Polar Distance.	Δα Struve-Groombridge.	Δα cos δ.
	°	s	s
2063	6·3	+1·24	+0·14
2196	6·7	+1·25	+0·15
2213	5·3	+1·98	+0·16
2315	6·5	+0·83	+0·09
2476	6·6	+0·56	+0·06
2548	6·6	−2·10	−0·24
3501	6·5	−0·30	−0·03
3820	4·8	+0·33	+0·03
3824	4·7	−0·47	−0·04
3970	6·6	−0·45	−0·05
4193	4·3	+0·20	+0·02

Zone 80° to 83°.

No. Groombridge.	Polar Distance.	Δα Struve-Groombridge.	Δα cos δ.
	°	s	s
424	9·6	+0·94	+0·16
426	9·4	+1·28	+0·21
506	9·2	−0·03	0·00
527	9·4	+0·67	+0·11
580	9·3	+0·58	+0·09
746	9·8	−0·05	−0·01
774	7·1	+0·43	+0·05
779	9·6	+0·47	+0·08
785	9·5	+0·52	+0·09
856	9·1	+0·99	+0·16
1255	8·4	−1·17	−0·17
1259	7·3	+0·54	+0·07
1278	8·8	−0·49	−0·07
1339	9·3	−0·50	−0·08
1355	9·7	+0·56	+0·09
1391	7·0	−0·85	−0·10
1431	7·1	−1·81	−0·22
1452	9·3	−0·56	−0·00
1463	9·3	−0·83	−0·13
1480	8·5	−0·08	−0·01
1537	7·9	−1·46	−0·20
1643	8·6	−0·85	−0·13
1662	8·6	−0·36	−0·05
1778	7·9	+1·01	+0·14

No. Groombridge.	Polar Distance.	Δα Struve-Groombridge.	Δα cos δ.
	°	s	s
1782	7·9	−0·07	−0·01
1845	8·1	+1·86	+0·26
1858	7·3	−0·13	−0·02
1909	8·7	+1·31	+0·20
1927	8·4	+1·34	+0·19
1977	8·5	+0·15	+0·02
2037	8·7	+0·05	+0·01
2071	8·3	+0·80	+0·12
2275	9·0	+1·93	+0·30
2276	9·0	+2·06	+0·32
2422	7·7	+0·29	+0·04
2456	9·7	+0·23	+0·04
3268	9·2	+0·40	+0·06
3276	9·2	+0·43	+0·07
3277	9·6	+0·33	+0·05
3370	8·2	+0·85	+0·12
3707	8·4	+0·23	+0·03
3709	8·4	+0·79	+0·12
3887	9·6	−0·10	−0·03
3928	7·8	−0·30	−0·04

Zone 70° to 80°.

No. Groombridge.	Polar Distance.	Δα Struve-Groombridge.	Δα cos δ.
	°	s	s
616	13·0	+0·53	+0·12
919	11·0	+0·71	+0·14
966	15·1	+0·69	+0·18
1217	12·8	+0·63	+0·14
1562	10·0	−0·71	−0·12
1650	13·3	+0·98	+0·23
1859	11·4	+0·58	+0·11
2094	11·6	+0·10	+0·02
2130	13·5	+0·21	+0·05
2172	15·1	+0·65	+0·17
2228	17·5	−0·09	−0·03
2236	17·5	+0·55	+0·17
2268	12·0	+1·46	+0·31
2294	11·6	+1·39	+0·28

No. Groombridge.	Polar Distance.	Δα Struve-Groombridge.	Δα cos δ.
	°	s	s
2334	13·7	+0·28	+0·07
2336	14·3	−0·69	−0·17
2349	13·8	+0·67	+0·16
2475	17·8	0·00	0·00
2477	17·8	−0·06	−0·02
2546	10·0	[−4·92]	
2547	10·0	[−4·98]	
2726	14·8	+0·08	+0·02
2930	16·0	+0·43	+0·12
3148	12·9	+0·43	+0·10
3373	10·1	−1·16	−0·20
3419	12·6	+0·16	+0·04
3508	14·4	−0·75	−0·19
3511	10·3	+1·74	+0·31
3809	12·2	−0·71	−0·15
3831	12·1	−0·82	−0·17
3834	14·7	−0·74	−0·19
4122	13·4	−0·04	−0·01

The stars connected by braces are components of pretty close doubles; the comparison has been made by using Groombridge's precessions reduced to Struve; the secular variations of the Radcliffe Catalogue, and the best proper motions attainable, either those of the *Fundamental Catalogue* of the *Berliner Jahrbuch*, those of Albrecht, or my own published or unpublished results. No error of any consequence has arisen from the occasional use of rather rough values, as the interval is everywhere less than nine years.

It will be seen on taking the means that the values of $\Delta\alpha \cos\delta$ vary but little with the declination, but are subject to rather large casual errors.

The mean value of $\Delta\alpha \cos\delta$ is $= +0^s{\cdot}034 \pm 0^s{\cdot}009$, and the probable error of the result from one star $= \pm 0^s{\cdot}093$ by sums of errors.

This is too large a quantity to be accounted for by the ordinary errors of observation. A liberal allowance for them in Struve's cases is $\pm 0^s{\cdot}03$ to $\pm 0^s{\cdot}04$, leaving at least $\pm 0^s{\cdot}084 = \sqrt{(0{\cdot}093)^2 - (0{\cdot}04)^2}$ for Groombridge. In one case, the double star 40 and 41 *Draconis*, the discrepancy arises from a mistake in Groombridge's reduction, as both stars are largely in error in his catalogue; and the stars *Groombridge* 1359 and 1418 are also suspicious; in both these cases Struve has three observations, and is confirmed by Schwerd and later authorities.

A small part of the visible periodicity is due to the use of an erroneous nutation-constant; but I think there is but little doubt that the main cause of discrepancy is instrumental error. Groombridge's meridian mark was rather too near—about half a mile, if the map of London, contained in Baedeker's guide-book, is trustworthy—and a previous investigation of Maskelyne's and Pond's observations has shown me that a polar deviation (Bessel's n) of $\pm 1''$ is not altogether to be avoided when the instrument is adjusted to the Meridian from time to time, and left for days to its own motions, without allowing for azimuth and level error in the modern fashion.

Singularly enough, the constant correction here indicated ($+0^s.034$ sec δ or $+0^s.034$ tan δ, very nearly the same thing) is but little more than would be derived from the observations of *Polaris* between June 23, 1806, and April 27, 1807, as given on p. xiii. of the Catalogue. The mean of the six double transits gives—

Excess of lower—upper culminations $= +2^s.05$, and this multiplied by one-half the cotangent of the star's declination gives $+0^s.03$ for the value of Bessel's n, or the polar deviation.

But these northern stars were mainly observed in 1806, 1807, and 1808. There is some difference between Struve's observations of 1814 and 1815, and those made later by himself and Argelander, which seem to be of the nature of personal equation. The comparison of all Groombridge's stars below 80°, which can be found in the later catalogues mentioned, gives $+0^s.12$ for the coefficient of tan δ, instead of $+0^s.035$. I do not think that any definite conclusion can be arrived at as to the real meaning of this term until it shall be possible to subject Groombridge's Right Ascensions to a careful revision with respect to signs of instrumental deviation.

This should not be a difficult task, employing his manuscripts, but would be greatly aided if their main portions were printed, as the original observations of Piazzi have been, so that any who were desirous to study them could have the opportunity.

There is no doubt, I think, that Groombridge's work deserves nearly as much attention in future ages as does Bradley's, allowance being made for the limited region in which he chiefly laboured; and I am quite sure that a careful revision of his results would repay the trouble spent on it in a great variety of directions.

At present it is almost impossible to obtain absolutely definitive values for the proper motions of the closer polars without very arbitrary assumptions as to the weight and systematic correction of Groombridge; and even the best ephemerides of these stars are in places quite uncertain, owing to the lack of trustworthy proper motions.

On the Reduction of Bessel's Precessions to those of Struve.

By A. A. Rambaut.

(*Communicated by Prof. R. S. Ball.*)

In the *Monthly Notices*, vol. xxxix. p. 364, Prof. Krueger has given a formula for reducing the annual precessions of Bessel to those of Struve, and Prof. Auwers has given tables in the *Fundamental Catalogue* containing corrections to Bessel's secular variations. Prof. Krueger's tables for the precessions in Right Ascension I have merely transcribed here, in order to have them along with the other tables, but I have put the corrections to the precessions in Declination in what appears to me a more convenient form. Prof. Auwers' tables are for reducing Bessel's secular variations for the year 1860, to those of Struve for 1875, whereas the object of this paper is to reduce the precessions, and secular variations of the precessions, according to Bessel, for any year, to their values as derived from Struve's constants for the same year. That this is not quite the same thing will appear from a comparison of the tables which follow with those of Prof. Auwers.

Let capital letters denote the values of the constants at the beginning of the century, and let those with B subscript refer to Bessel, and those with S subscript to Struve.

Then

$$m_B = M_B + m'_B.t = 46''04367 + 0''000308645 0 \cdot t$$
$$m_S = M_S + m'_S.t = 46\cdot0623 + 0\cdot0002849\,.t$$
$$n_B = N_B + n'_B.t = 20\cdot05957 - 0\cdot0000970204\,.t$$
$$n_S = N_S + n'_S.t = 20\cdot0607 - 0\cdot0000863\,.t$$

Then the annual precession according to Bessel (P_B).

$$= \tfrac{1}{15}\, m_B + \tfrac{1}{15}\, n_B \tan\delta \sin\alpha$$

And

$$P_S = \tfrac{1}{15}\, m_S + \tfrac{1}{15}\, n_S \tan\delta \sin\alpha$$

therefore

$$P_S - P_B = \tfrac{1}{15} \cdot \frac{m_S n_B - m_B n_S}{n_B} + \frac{n_S - n_B}{n_B}\, P_B = k + l P_B .$$

The factor l being at its greatest equal to 0·00010823, it is sufficient to take P_B to two places of decimals in this equation to obtain the result correct to five.

The values of k and l for every tenth year during the century, which are given in Table I., are taken from Prof. Krueger's paper in the *Monthly Notices*, correcting an evident misprint which has occurred in the latter.

Again, Bessel's precession in declination (Q_B)

$$Q_B = n_B \cos \alpha, \text{ and } Q_S = n_S \cos \alpha,$$

whence

$$Q_S - Q_B = (n_S - n_B) \cos \alpha.$$

The values of this are given in Table II. for every tenth year during the century, and for every hour of Right Ascension in units of the fourth decimal. They are always of the same sign as Q_B.

The secular variation in α is

$$P' = \tfrac{100}{15}\left(m' + \frac{n^2}{2K} \sin 2\alpha\right) + \tfrac{100}{15}\left(n' \sin \alpha + \frac{mn}{K} \cos \alpha\right) \tan \delta + \tfrac{100}{15} \frac{n^2}{K} \sin 2\alpha \tan^2 \delta,$$

where

$$K = 206265,$$

or

$$P' = A + B \tan \delta + C \tan^2 \delta.$$

Therefore

$$P'_S - P'_B = (A_S - A_B) + (B_S - B_B) \tan \delta + (C_S - C_B) \tan^2 \delta.$$

Also the secular variation in δ is

$$Q' = 100\left(n \cos \alpha - \frac{mn}{K} \sin \alpha\right) - \frac{100}{K} n^2 \sin^2 \alpha \tan \delta = A' + B' \tan \delta,$$

and therefore

$$Q'_S - Q'_B = (A'_S - A'_B) + (B'_S - B'_B) \tan \delta.$$

We have

$$A_S - A_B = \tfrac{100}{15}\left\{ m'_S - m'_B + \frac{1}{2K}(n_S^2 - n_B^2) \sin 2\alpha \right\}.$$

From the values given above we find

$$\tfrac{100}{15}(m'_S - m'_B) = -0^s.0001583.$$

Also

$$\frac{100}{30K}\left\{ n_S^2 - n_B^2 \right\} = \frac{100}{30K}\left\{ N_S^2 - N_B^2 + 2(N_S n'_S - N_B n'_B)t + \left(n'^2_S - n'^2_B\right)t^2 \right\}$$

The last term in this is quite inappreciable, and we find

$$\frac{100}{30K}\left(N_S^2 - N_B^2\right) = +0^s.0000006,$$

and

$$\frac{100}{15K}\left(N_S n'_S - N_B n'_B\right) = +0^{s}.0000000069,$$

whence during the century

$$A_S - A_B = -0^{s}.000158.$$

Again

$$A'_S - A'_B = 100\left\{(n'_S - n'_B)\cos\alpha - \frac{m_S n_S - m_B n_B}{K}\sin\alpha\right\},$$

and we have

$$100(n'_S - n'_B) = +0^{s}.00107.$$

Also

$$\frac{100}{K}\left\{m_S n_S - m_B n_B\right\} = \frac{100}{K}\left\{M_S N_S - M_B N_B) + (m'_S N_S - m'_B N_B + M_S n'_S - M_B n'_B)t + (m'_S n'_S - m'_B n'_B)t^2\right\}.$$

The third term in this is also inappreciable, and we find

$$m'_S N_S - m'_B N_B = -0^{s}.0004759923,$$

and

$$M_S n'_S - M_B n'_B = +0^{s}.0004919990,$$

and therefore

$$m'_S N_S - m'_B N_B + M_S n'_S - M_B n'_B = +0^{s}.0000160067,$$

whence it is clear that the coefficient of sin α in the value of

$$A'_S - A'_B \text{ is } \frac{100}{K}\left(M_S N_S - M_B N_B\right) = +0^{s}.00020642.$$

Thus we have

$$A'_S - A'_B = (10^{s}.7\cos\alpha - 2^{s}.064\sin\alpha)$$

in units of the fourth decimal.

The values of this correction for every hour of Right Ascension are given in Table III.

The value of $A'_S - A'_B$ in seconds of arc for any value of α is fifteen times that of $B_S - B_B$ in seconds of time for $\alpha + 6^h$. Thus we obtain the correction to B_B from the following table, which is immediately deducible from Table III.

h	$B_S - B_B$	h	h	$B_S - B_B$	h	h	$B_S - B_B$	h
0	+1·4	12	4	+6·9	16	8	+5·5	20
1	+3·2	13	5	+7·2	17	9	+4·1	21
2	+4·8	14	6	+7·1	18	10	+2·4	22
3	+6·0	15	7	+6·5	19	11	+0·5	23
						12	−1·4	24

Between 12^h and 24^h take the correction with an opposite sign. The correction is given in units of the fifth decimal. Table IV. gives the value of this multiplied by $\tan\delta$.

It remains to find the values of $C_S - C_B$ and of $B'_S - B'_B$.

We have

$$C_S - C_B = \frac{100}{15K}\left(n_S^2 - n_B^2\right) \sin 2\alpha$$

$$= \left\{ +0^{s}\cdot 0000012 + 0^{s}\cdot 00000000138 \,.\, t \right\} \sin 2\alpha.$$

Although this term is very small, yet being multiplied by $\tan^2\delta$, it has an effect on stars whose declinations exceed 50°. In Table V. are given the values of the coefficient of $\sin 2\alpha$ for every tenth year, and in Table VI. the values of $\sin 2\alpha \tan^2\delta$. The product of these two quantities, along with the number taken from Table IV., and the constant $-0^s\cdot 000158$, gives the whole correction to the secular variation of the precession in α.

Again

$$B'_S - B'_B = -\frac{100}{K}\left(n_S^2 - n_B^2\right) \sin^2\alpha$$

$$= -(0''\cdot 000018 + 0''\cdot 000000207 \,.\, t) \sin^2\alpha,$$

this multiplied by $\tan\delta$, if $t = 100$ and $\alpha = 6^h$, does not amount to $0''\cdot 0001$, as long as δ is less than 69°, and as its greatest value—for 80°—within the limits of these tables is $0''\cdot 00022$, it may be safely neglected. We have thus the whole correction to Q_B from Table III. in units of fourth decimal.

If, however, it be thought necessary to correct for this term, the numerical coefficient is given in Table VII. for every twentieth year during the century, and the corresponding factor in Table VIII. The whole correction, then, to the secular variation of the precession in δ, in units of the fourth decimal, is the number taken from Table III., along with the product of those taken from Tables VII. and VIII.

Example—

$$\alpha = 20^h\ 24^m\ 27^s\cdot 5, \qquad \delta = -10^\circ\ 20'\ 41''$$

for 1855.

The annual precession in α with Bessel's constants $= + 3^s\cdot26785$

" " δ " " $= +11''\cdot8200$

Secular variation of the precession in α $= -0^s\cdot00785$

" " " δ $= +0''\cdot3793$

From Table I. we find for 1855

$$k = 0\cdot000895 \text{ and } l = 0\cdot0000842.$$

We have then

$P_n =$	$+ 3\cdot26785$
$3\cdot27 \times 0\cdot0000842 =$	275
$k =$	895
$P_s =$	$+ 3\cdot26902$

Also

$Q_n =$	$+11\cdot8200$
Correction from Table III. $=$	10
$Q_s =$	$+11\cdot8210$

Again,

$P'_n =$	$- 0\cdot00785$
Correction from Table IV. $=$	$+ 09$
" " Tables V. and VI. $=$	00
$A_s - A_n =$	$- 158$
	$- 0\cdot00800$

And, finally,

$Q'_n =$	$+ 0\cdot3793$
Correction from Table III. $=$	$+ 79$
$Q'_s =$	$+ 0\cdot3801$

In order to show the difference between these tables and those of Prof. Auwers, in the *Fundamental Catalogue*, let us compare the secular variations in α of a star for which $\alpha = 3^h$ and $\delta = 78°$ for 1875.

By direct calculation we find

$$P'_s = +0^s\cdot393557 \text{ and } P'_n = +0^s\cdot393376.$$

The correction from Table IV.	$= +28\cdot3$
" from Tables V. and VI.	$= + 5\cdot1$
$A_s - A_n =$	$- 15\cdot8$
	$+17\cdot6$

Which would give $P'_s = 0^s\cdot393552$. Prof. Auwers' correction is 14·2, which would make $P'_s = 0^s\cdot393518$.

Table I.

	k	l		k	l		k	l
1800	+0·00107	+0·00005484	1840	+0·00094	+0·00007619	1880	+0·00081	+0·00009755
1810	0·00104	0·00006018	1850	0·00091	0·00008153	1890	0·00078	0·00010289
1820	0·00101	0·00006551	1860	0·00088	0·00008687	1900	0·00075	0·00010823
1830	0·00098	0·00007085	1870	0·00085	0·00009221			

Table II.

α	1800.	1810.	1820.	1830.	1840.	1850.	1860.	1870.	1880.	1890.	1900.	α
0^h or 24^h	11·3	12·4	13·4	14·5	15·6	16·7	17·7	18·8	19·9	20·9	22·0	12^h or 12^h
1 „ 23	10·9	12·0	12·9	14·0	15·1	16·1	17·1	18·2	19·2	20·2	21·3	13 „ 11
2 „ 22	9·8	10·7	11·6	12·6	13·5	14·5	15·3	16·3	17·2	18·1	19·1	14 „ 10
3 „ 21	8·0	8·8	9·5	10·3	11·0	11·8	12·5	13·3	14·1	14·8	15·6	15 „ 9
4 „ 20	5·6	6·2	6·7	7·2	7·8	8·3	8·8	9·4	10·0	10·5	11·0	16 „ 8
5 „ 19	2·9	3·2	3·5	3·8	4·0	4·3	4·6	4·9	5·2	5·4	5·7	17 „ 7
6 „ 18	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	18 „ 6

Table III.

α	Correction.	α	α	Correction.	α	α	Correction.	α	α	Correction.	α
0^h	+10·7	12^h	4^h	+3·6	16^h	7^h	−4·8	19^h	10^h	−10·3	22^h
1	+ 9·8	13	5	+0·8	17	8	−7·1	20	11	−10·9	23
2	+ 8·2	14	6	−2·1	18	9	−9·0	21	12	−10·7	24
3	+ 6·1	15									

Between 12^h and 24^h take the correction with an opposite sign.

Table IV.

		0°	10°	20°	30°	40°	50°	60°	65°	70°	72°	74°	76°	78°	80°		
0^h	+	0·0	0·2	0·5	0·8	1·2	1·6	2·4	2·9	3·8	4·	4·8	5·5	6·5	7·8	−	12^h
1	+	0·0	0·6	1·2	1·8	2·7	3·8	5·5	6·8	8·7	9·8	11	12·7	14·9	18·0	−	13
2	+	0·0	0·8	1·7	2·8	4·0	5·7	8·2	10·2	13·1	14·6	16·6	19·1	22·4	27·0	−	14
3	+	0·0	1·1	2·2	3·5	5·1	7·2	10·4	12·9	16·5	18·5	21·0	24·1	28·3	34·1	−	15
4	+	0·0	1·2	2·5	4·0	5·8	8·2	11·9	14·7	18·9	21·2	24·0	27·5	32·3	39·0	−	16
5	+	0·0	1·3	2·6	4·2	6·1	8·6	12·6	15·5	19·9	22·3	25·3	29·1	34·0	41·1	−	17
6	+	0·0	1·3	2·6	4·1	6·0	8·5	12·4	15·3	19·6	22·0	24·9	28·6	33·5	40·4	−	18
7	+	0·0	1·1	2·4	3·8	5·5	7·8	11·3	14·0	18·0	20·1	22·8	26·2	30·7	37·1	−	19
8	+	0·0	1·0	2·0	3·2	4·6	6·5	9·5	11·8	15·1	16·9	19·2	22·0	25·8	31·1	−	20
9	+	0·0	0·7	1·5	2·4	3·4	4·8	7·1	8·7	11·2	12·5	14·2	16·3	19·1	23·1	−	21
10	+	0·0	0·4	0·9	1·4	2·0	2·8	4·1	5·1	6·5	7·3	8·3	9·5	11·1	13·4	−	22
11	+	0·0	0·1	0·2	0·3	0·4	0·6	0·9	1·1	1·4	1·6	1·8	2·1	2·4	3·0	−	23
12	−	0·0	0·2	0·5	0·8	1·2	1·6	2·4	2·9	3·8	4·2	4·8	5·5	6·5	7·8	+	24

The signs in the second column are for North, and those in the second last column for South Declinations and Right Ascensions between 0^h and 12^h. Between 12^h and 24^h take the correction with an opposite sign.

TABLE V.

1800	0·12	1840	0·18	1880	0·23
1810	0·13	1850	0·19	1890	0·24
1820	0·15	1860	0·20	1900	0·26
1830	0·16	1870	0·22		

Units of fifth decimal.

TABLE VI.

h	m	55°	60°	64°	68°	70°	72°	74°	76°	78°	80°
0	0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	30	0·5	0·8	1·1	1·6	2·0	2·5	3·2	4·2	5·7	8·3
1	0	1·0	1·5	2·1	3·1	3·8	4·7	6·1	8·0	11·0	16·1
	30	1·4	2·1	3·0	4·3	5·3	6·7	8·6	11·4	15·6	22·7
2	0	1·8	2·6	3·6	5·3	6·6	8·2	10·6	13·9	19·1	27·8
	30	2·0	2·9	4·1	5·9	7·3	9·2	11·8	15·3	21·4	32·0
3	0	2·0	3·0	4·2	6·1	7·6	9·5	12·2	16·1	22·1	32·1

The correction for $6^h - \alpha$ = + the correction for α.
" " " 6 + α = − " " " "
" " " 12 + α = + " " " "

TABLE VII.

1800	0·18	1840	0·26	1880	0·35
1820	0·22	1860	0·31	1900	0·39

TABLE VIII.

	55°	60°	65°	70°	75°	80°	
0^h or 24^h	0·0	0·0	0·0	0·0	0·0	0·0	12^h or 12^h
1 " 23	0·1	0·1	0·1	0·2	0·2	0·4	11 " 13
2 " 22	0·4	0·4	0·5	0·7	0·9	1·4	10 " 14
3 " 21	0·7	0·9	1·1	1·4	1·9	2·8	9 " 15
4 " 20	1·1	1·3	1·6	2·1	2·8	4·2	8 " 16
5 " 19	1·3	1·6	2·0	2·6	3·5	5·3	7 " 17
6 " 18	1·4	1·7	2·2	2·8	3·7	5·7	6 " 18

For North Declinations the factor is negative, and positive for South.

Dunsink:
1885, *Dec.* 10.

Observations of Double Stars at Windsor, New South Wales.

By John Tebbutt.

The accompanying table contains the results of all the double-star observations made by me to the present date. The 4½-inch Equatorial was employed throughout, but it was not driven by clockwork. The steadiness and uniform motion of the slow motion arrangement in Right Ascension were very satisfactory. The greatest difficulty in the work of observation consisted in the measurement of distances when the position angle approached 90° or 270°, but it will be seen that these conditions seldom occurred.

Name of Star.	Observed Magnitudes.	Approx. place at beginning of Year of Observation. R.A. h m	Declin. South. ° ′	Year, Month, and Day of Observation.	Fraction of Year.	Position Angle. °	Distance. ″	No. of Measures. Position.	No. of Measures. Distance.	Weight of Result.	Magnifying Power.	Obs. E. or W. of Merid.	Ref. No. to Remarks.
β Toucani	—	0 26·1	63 37	1882 Mar. 18	·21	170·4	27·32	8	7	3	180	W	1
B. A. C. 246	7, 8	0 47·9	70 9	1880 Mar. 15	·20	79·1	20·50	4	4	2	180	W	2
p Eridani	—	1 35·2	56 48	„ „ 8	·18	231·9	6·51	10	10	3	180	W	3
„	—	„	„	„ „ 9	·19	233·3	6·23	7	7	2	180	W	4
„	—	„	„	„ May 30	·41	233·4	6·55	6	2	2	—	E	5
„	—	„	„	„ Oct. 7	·77	235·0	6·57	6	6	2	320	E	6
„	—	„	„	„ „ 11	·78	234·5	6·24	10	10	2	320	E	7
„	—	1 35·3	56 48	1882 Mar. 6	·18	233·0	7·01	5	5	2	180	W	8
„	6, 6	1 35·4	56 47	1885 Mar. 11	·19	230·5	7·10	10	10	—	180	W	9
θ Eridani	4½, 5½	2 53·8	40 47	1882 Mar. 11	·19	85·0	8·44	5	5	3	180	W	10
12 Eridani	4, 7	3 7·1	29 27	„ „ 13	·20	318·0	—	10	—	2	180	W	11
Lacaille 1181	6½, 7	3 35·5	40 44	„ „ 13	·20	227·5	7·96	3	3	2	180	W	12
f Eridani	5, 5¼	3 44·2	37 59	„ „ 11	·19	203·0	7·25	5	5	3	180	W	13
θ Reticuli	6½, 8	4 16·4	63 33	„ „ 17	·21	5·4	—	7	—	1	180	W	14
Lacaille 1475	6½, 6½	4 21·9	57 20	„ „ 13	·20	236·2	6·36	5	5	2	180	W	15
ι Pictoris	5, 6	4 48·3	53 40	„ „ 11	19	58·2	12·18	5	5	3	180	W	16
Lacaille 2145	8¼, 8½	6 1·7	48 27	1881 Mar. 19	·21	12·7	2·50	9	5	2	180	W	17
„	8¼, 8½	„	„	„ „ 21	·22	10·1	2·42	12	4	2	180	W	18
„	—	6 1·7	48 27	1882 Feb. 21	·14	24·4	—	5	—	1	180	W	19
„	—	„	„	„ „ 25	·15	24·6	—	10	—	1	180	W	20
„	—	„	„	„ Mar. 6	·18	23·3	—	12	—	2	180	W	21

Name of Star.	Observed Magnitudes.	Approx. place at beginning of Year of Observation. R.A.	Declin. South.	Year, Month, and Day of Observation.	Fraction of Year.	Position Angle.	Distance.	No. of Measures. Position.	Distance.	Weight of Result.	Magnifying Power.	Obs. E. or W. of Merid.	Ref. No. to Remarks.
		h m	° ′			°	″						
Lacaille 2145	—	6 1·7	48 27	1882 Mar. 22	·22	19·7	—	10	—	1	180	W	22
,,	—	,,	,,	,, Nov. 24	·90	16·2	—	10	—	—	320	E	23
,,	7, 8	6 1·8	48 27	1885 Mar. 6	·18	20·4	—	10	—	—	180	W	24
,,	7, 7½	,,	,,	,, ,, 10	·19	19·2	—	15	—	2	180	W	25
Brisbane 1201	6½, 8	6 11·9	65 30	,, ,, 10	·19	116·8	20·52	7	7	2	180	W	26
V Puppis	6, 8	6 35·5	48 7	1881 Mar. 16	·20	318·2	12·69	9	10	3	180	W	27
Lacaille 2640	7½, 8	7 1·4	59 0	,, ,, 24	·23	82·4	—	8	—	1	320	W	28
,,	7½, 8	,,	,,	,, ,, 24	·23	79·6	—	8	—	1	180	W	29
,,	—	7 1·4	59 0	1882 Mar. 22	·22	77·8	—	10	—	1	180	W	30
Lacaille 2685	7½, 7½	7 8·1	55 24	1885 Mar. 11	·19	45·8	7·10	5	5	—	180	W	31
γ Argûs, A. B.	2, 5	8 5·9	46 59	1881 Mar. 21	·22	219·0	42·46	5	5	3	180	W	32
,,	2, 5	,,	,,	,, ,, 22	·22	219·7	—	10	—	3	180	E	33
,,	2, 5	,,	,,	,, ,, 24	·23	219·5	—	3	—	3	180	W	34
γ Argûs, A. C.	2, 7½	8 5·9	46 59	,, ,, 22	·22	151·2	—	10	—	3	180	E	35
,,	2, 7½	,,	,,	,, ,, 24	·23	151·5	64·42	4	3	3	180	W	36
Lacaille 4031	8½, 8¼	9 43·7	34 28	,, ,, 17	·21	126·5	5·61	5	5	1	130	E	37
o Argûs	3, 8	9 44·1	64 31	1880 Apr. 16	·29	125·4	4·94	5	5	2	—	W	38
Lacaille 4268	—	10 15·5	64 6	1885 Mar. 14	·20	317·3	2·48	10	5	3	180	E	39
s Velorum	6 6	10 26·9	44 27	1881 Mar. 17	·21	217·7	13·68	5	5	3	180	E	40
,,	6, 6½	10 26·9	44 28	1882 Mar. 10	·19	218·9	12·68	5	5	2	180	E	41
,,	6, 6¼	10 27·0	44 29	1885 Mar. 7	·18	218·9	12·92	10	10	3	180	E	42

Name of Star.	Observed Magnitudes.	Approx. place at beginning of Year of Observation. R.A. h m	Declin. South. ° ′	Year, Month, and Day of Observation.	Fraction of Year.	Position Angle. °	Distance. ″	No. of Measures. Position.	Distance.	Weight of Result.	Magnifying Power.	Obs. E. or W. of Merid.	Ref. No. to Remarks.
Lacaille 4350	6½, 7	10 28·6	54 47	1882 Mar. 10	·19	29·4	25·63	3	3	2	180	E	43
h 4392	8, 8	10 53	70 44	1885 Mar. 19	·21	160·0	25·01	5	5	2	130	E	44
α Crucis	—	12 19·9	62 26	1880 Feb. 28	·16	120·5	5·11	3	3	1	180	W	45
,,	—	,,	,,	,, Mar. 9	·19	120·9	4·75	3	3	2	—	W	46
γ Centauri	—	12 35·0	48 19	1882 Mar. 22	·22	2·1	—	10	—	3	320	E	47
γ Virginis	—	12 35·6	0 47	1880 May 20	·38	157·2	5·83	6	6	2	320	W	48
,,	—	,,	,,	,, ,, 28	·41	157·1	5·65	7	6	2	—	W	49
α Centauri	—	14 31·5	60 20	,, Feb. 28	·16	185·1	5·10	3	2	1	180	W	50
,,	—	,,	,,	,, Mar. 8	·18	182·6	5·08	6	5	1	—	W	51
,,	—	,,	,,	,, ,, 8	·18	186·7	4·97	8	8	2	—	W	52
,,	—	,,	,,	,, ,, 8	·18	181·2	5·72	3	3	2	180	E	53
,,	—	,,	,,	,, May 7	·35	186·4	5·31	10	10	3	320	E	54
,,	—	,,	,,	,, ,, 28	·41	184·0	5·94	3	3	2	—	E	55
,,	—	,,	,,	,, ,, 29	·41	185·2	5·43	10	10	2	—	E	56
,,	—	,,	,,	,, Oct. 8	·77	188·7	6·13	8	8	3	320	W	57
,,	—	14 31·5	60 21	1881 Aug. 24	·64	191·8	7·89	8	8	2	180	W	58
,,	—	,,	,,	,, ,, 30	·66	194·5	8·00	8	8	2	—	W	59
,,	2, 3	14 31·6	60 21	1882 Mar. 22	·22	194·6	8·70	7	7	3	320	E	60
,,	—	14 31·7	60 21	1884 July 9	·52	199·5	12·92	10	10	2	180	E	61
,,	—	,,	,,	,, ,, 9	·52	200·9	13·01	10	10	2	180	W	62
,,	—	,,	,,	,, ,, 12	·53	198·9	12·68	6	6	2	180	E	63

Name of Star.	Observed Magnitudes.	Approx. place at beginning of Year of Observation. R.A. h m	Declin. South. ° ′	Year, Month, and Day of Observation.	Fraction of Year.	Position Angle.	Distance.	No. of Measures. Position.	Distance.	Weight of Result.	Magnifying Power.	Obs. E. or W. of Merid.	Ref. No. to Remarks.
α Centauri	—	14 31·7	60 21	1884 July 12	·53	199°·4	13″·07	6	6	1	180	W	64
,,	—	,,	,,	,, ,, 18	·55	198·9	12·98	8	8	3	180	E	65
,,	—	,,	,,	,, ,, 18	·55	201·2	12·92	8	8	2	180	W	66
,,	—	14 31·8	60 22	1885 July 11	·52	198·6	13·47	4	5	3	—	E	67
,,	—	,,	,,	,, ,, 11	·52	201·7	14·03	4	5	1	—	W	68
,,	—	,,	,,	,, ,, 27	·57	199·8	14·40	7	7	3	—	E	69
,,	—	,,	,,	,, ,, 27	·57	202·0	14·17	7	7	2	—	W	70
,,	—	,,	,,	,, ,, 31	·58	200·8	14·08	10	10	3	—	E	71
,,	—	,,	,,	,, ,, 31	·58	201·2	14·17	10	10	2	—	W	72
,,	—	,,	,,	,, Aug. 3	·59	201·1	—	10	—	3	—	E	73
,,	—	,,	,,	,, ,, 3	·59	201·2	—	10	—	2	—	W	74
α Circini	—	14 33·2	64 28	,, ,, 8	·60	239·2	15·95	5	5	1	—	W	75
μ Lupi	5, 5½	15 10·3	47 26	1882 Mar. 10	·19	160·5	—	8	—	—	320	E	76
Lacaille 6477	7, 7	15 37·4	65 5	1885 Aug. 8	·60	152·2	2·32	5	5	2	—	W	77
ξ Lupi	6, 6½	15 49·3	33 37	1881 Aug. 30	·66	49·9	10·55	5	5	3	—	W	78
η Lupi	4, 7½	15 52·2	38 3	,, Sept. 8	·69	20·3	14·93	6	6	3	180	W	79
,,	5, 9	15 52·5	38 4	1885 Aug. 1	·58	19·7	15·21	5	5	2	180	W	80
36 Ophiuchi	6, 6	17 8·0	26 25	1881 Sept. 8	·69	200·6	4·77	5	5	2	320	W	81
Lacaille 7267	7½, 8	17 18·4	45 44	1885 Aug. 1	·58	264·5	2·85	10	5	3	180	E	82
κ Coronæ Aust.	5⅔, 7	18 25·2	38 49	1881 Sept. 10	·69	0·7	21·95	3	3	1	320	W	83
Lacaille 7924	8, 8	18 53·2	63 57	1885 Aug. 5	·59	110·7	2·14	10	5	1	—	E	84

Name of Star.	Observed Magnitudes.	Approx. place at beginning of Year of Observation. R.A. h m	Declin. South. ° ′	Year, Month, and Day of Observation.	Fraction of Year.	Position Angle. °	Distance. ″	No. of Measures. Position.	Distance.	Weight of Result.	Mag. nifying Power.	Obs. E. or W. of Merid.	Ref. No. to Remarks.
λ 5092	8, 8½	19 5	47 33	1885 July 30	·58	351·8	17·58	5	5	3	180	E	85
Lacaille 8443	7½, 8	20 28·0	75 45	„ „ 31	·58	15·9	17·46	7	7	3	—	E	86
Lacaille 8550	7, 7	20 42·0	62 51	„ Aug. 4	·59	96·9	3·12	8	8	3	180	E	87
Lacaille 8687	8½, 8½	21 2·0	55 2	„ July 27	·57	122·5	3·65	10	5	3	90	E	88
θ Indi	6, 8	21 11·7	53 56	„ „ 30	·58	288·2	4·40	5	5	3	180	E	89

Remarks.

1. It was difficult to decide which was the brighter component, but that in the north preceding quadrant was probably so.

3, 4, 5, 6, 7. The same difficulty presented itself, but I think the north following was the brighter.

8. Although the components were very nearly equal, there was no doubt about the north following star being the brighter.

9. It was impossible to determine which was the brighter. 11. Estimated distance = 1″·5. 14. Companion seen with difficulty.

15. It was difficult to decide which was the brighter. 17. One or both of these stars probably variable 24. Estimated distance = 1″

25. On setting the position circle to 12° the deviation of the line joining the components from parallelism to the position threads was very sensible. 28, 29. Estimated distance = 2″·0. 30. Estimated distance = 2″·5.

31. Impossible to decide which was the brighter. 37. The components were equal. 40. The following component the brighter.

41, 42. Both the Cape and Sydney Catalogues make the components equal, and place the angle in the first quadrant. On March 10, 1882, and March 7, 1885, the north following star was decidedly the brighter. 44. The north preceding star probably the brighter.

47. Components exactly equal: estimated distance = 2″·0. 49. The north star apparently the brighter.

67, 68. The distances are deduced from the observed position angle and differences of declination.

76. Estimated distance = 2″·0. 80. The Sydney Catalogue gives the distances as 7·06 in 1879.

81. Difficult to decide which was the brighter, but probably the northern star. The magnitudes assigned to the components in the *Handbook of Double Stars* by Crossley, Gledhill, and Wilson are 4½ and 6½. 84. Components equal, hazy, and ill-defined.

Windsor, N.S. Wales:
1885, *Oct.* 9.

Observations of Magnitude of Nova Andromedæ made at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, M.A., F.R.S.*)

The following estimations of magnitude of *Nova Andromedæ* were made with the 10-foot Equatorial of 7-inch aperture, except on September 19 and 21, when the Heliometer, of which the aperture is 7·5, was used.

Day and Hour.	h	Observed Magnitude.	Observer.	Power used.
Sept. 9	10	8·0	R.	45 (*a*)
17	10	8·5	W.	45 (*b*)
18	9	8·5	W.	45
19	10½	8·5	W.	45
21	10½	9·2	W.	45
22	8	9·5	W.	45
	9½	9·3	R.	45
24	10	9·6	W.	45 (*c*)
25	9¾	8·7 (*d*)	R.	45
	9¾	9·6	W.	45
26	8½	10·0	F.B.	125
29	9½	10·7	F.B.	125
	9½	11·0	R.	125
	9½	10·3	W.	45
30	9	10·7	F.B.	125
Oct. 1	8	10·9	W.	125
3	9½	10·8	F.B.	125 and 160
5	6½	10·7	R.	160
	8	10·7	F.B.	125
	9	10·6	W.	125 (*e*)
7	8	11·3	F.B.	125
12	10	11·2	F.B.	125
16	9	11·2	R.	160
	9½	11·1	F.B.	160
27	7½	11·7	F.B.	125
	7½	12·0	W.	125
Nov. 5	9½	12·6	F.B.	125
28	7½	13·5	F.B.	125 and 160
Dec. 1	8	—	F.B.	125 (*f*)
4	8	13·6	F.B.	160 and 295 (*g*)
10	8	14·0	F.B.	295 (*h*)

The following observations of magnitude were made with the Transit circle:—

Day and Hour.	h	Observed Magnitude.	Observer.	Power used.
Sept. 21	12½	9·7	R.	80
25	12½	9·5	R.	115
26	12¼	9·7	F.B.	143
30	12	10·2	F.B.	143
Oct. 5	11¾	10·4	R.	143

Remarks.

(*a*) Reddish; very slightly fainter than Arg. Z + 40°, No. 165 (mag. 7·9) and No. 167 (mag. 7·7).

(*b*) Yellowish-red. Suspicion of a faint companion. With power 125 *Nova* duller, like a comet nucleus.

(*c*) With power 125 *Nova* dull and flat, stars bright and sharp.

(*d*) This observation was hurriedly made, the observer being on duty with the Transit circle. Transit circle mag. by Observer R. gives 9·5.

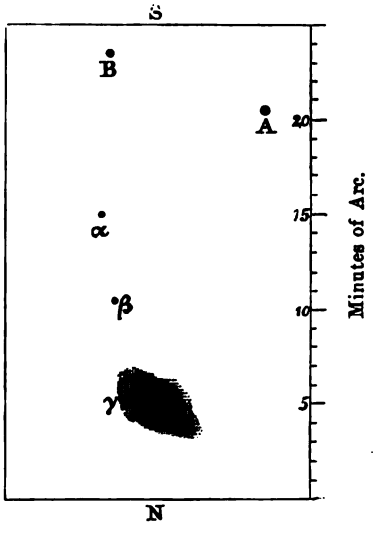
(*e*) Seems somewhat brighter than on Oct. 1.

(*f*) *Nova* and condensation still distinctly visible; mag. not observed.

(*g*) Condensation more distinct than *Nova*, which was extremely faint.

(*h*) *Nova* only just discernible; nucleus or condensation of nebula and γ distinctly visible.

The following is a chart of approximate positions of the stars used for comparison of magnitudes:—



The adopted observed magnitudes of the above comparison stars are as follows:—

A = 9·0	β = 11·4
B = 9·0	γ = 13·0
α = 11·0	

The approximate observed places for 1885, January 1, obtained with the 10-foot Equatorial, are—

	Approx. R.A. h m s	Approx. N.P.D. °	
α ...	0 36 11 ...	49 31·4	
B ...	0 36 13 ...	49 40·3	Arg. $z+40°$, No. 145
β ...	0 36 17 ...	49 27·1	
γ ...	0 36 18 ...	49 22·1	
Nova ...	0 36 27 ...	49 21·7	
A ...	0 36 58 ...	49 37·2	Arg. $z+40°$, No. 149

Observers.—W.=Mr. W. Wickham; R.=Mr. W. H. Robinson; F.B.=Mr. F. A. Bellamy.

Radcliffe Observatory, Oxford:
1885, *Dec.* 11.

On a Suspected New Variable Star in Corona Borealis.

By J. E. Gore.

With reference to Mr. Chambers' paper in the Supplementary Number of the *Monthly Notices* (No. 9, vol. xlv.), I beg to point out that the red star *Birmingham* 361 (=Schj. 182) is identical with the known variable star *V Coronæ* (No. 109 of my *Catalogue of Known Variable Stars*), its variability having been discovered by Dunér in 1878, and confirmed by the observations of Chandler, Hartwig, Safarik, Schmidt, and Wilsing. The variation is from $7^{m}5$ to 12^{m}, and the period about $359\frac{1}{2}$ days. The following maxima have been observed:—

1878, Oct. 5 ...	... Dunér.
1879, Oct. 12 ...	... Schmidt.
1881, Oct. 3 ...	... Schmidt.
1882, Sept. 15·6 ...	... Schmidt.
1883, Sept. 24 ($7^{m}7$)	... Chandler.
1883, Sept. 5 ...	... Schmidt.

The red star observed by Mr. Chambers on August 13, 1885, was most probably *V Coronæ*, as a maximum was due this year early in September. I may add that, according to Chandler, the period given above agrees well with the invisibility of the star to *Birmingham* in 1873 and 1874, and the observations by Ball in 1876, and by Dreyer in 1879 and 1880.

Ballysodare, Co. Sligo:
1885, *Nov.* 19.

Occultation of Uranus, 1885, *December* 1. By the Rev. S. J. Johnson.

Disappearance at the Moon's bright limb took place at a point in a line with *Marius* north of *Grimaldi*, at $4^{h}\ 56^{m}\ 16^{s}$ morning. Sky perfectly clear. Reappearance $6^{h}\ 6^{m}\ 42^{s}$, also in a clear sky. Time by sextant. With power of 50 on $3\frac{1}{4}$ inches, planet rather minute at immersion; at emersion bright and distinct, somewhat between a planetary disc and a star. Some interest is attached to this phenomenon from the fact of the planet having disappeared six minutes before the predicted time in March 1871 (calculated from former tables), several observers being on that occasion disappointed of the observation.

Melplash Vicarage, Bridport:
1885, *Dec.* 8.

Observations of Comets—Brooks, Fabry, and Barnard—made at Dun Echt Observatory with the Filar Micrometer of the 15-inch Refractor.

(Communicated by the Earl of Crawford and Balcarres.)

Object.	Date.	Dun Echt Mean Time.	Comet—Star. Δα	Comet—Star. Δδ	α Comet.	δ Comet.	Observer.	Remarks.
	1885	h m s	m s	′ ″	h m s	° ′ ″		
Brooks ...	Oct. 5	9 3 41	+0 14·98	−0 4·1	17 29 38·11	+41 35 41·4	L. B.	Very faint, 3′ diam.
Fabry ...	Dec. 7	8 20 59	+2 22·57	−3 31·8	0 25 10·02	+20 52 45·4	R. C.	Diam. 40″, brighter towards the preceding side.
Barnard ...	7	12 21 45	+3 42·26	−1 54·9	4 12 29·07	+ 5 3 52·9	R. C.	Diam. 1′, considerably brighter in the middle.

Adopted Mean Places of Comparison Stars for 1885·0.

1885	α	Redn.	δ	Redn.	Authorities.
	h m s	s	° ′ ″	″	
Oct. 5	17 29 22·46	+0·67	+41 35 21·2	+24·3	Connected with B. W_2. 812.
	17 27 38·27		+41 35 23·8		B. W_2. 812.
Dec. 7	0 22 44·03	+3·42	+20 55 52·1	+25·1	Bonn Observations, Vol. VI. +20°, 47.
7 (*bis*)	4 8 42·70	+4·11	+ 5 5 45·8	+ 2·0	B. W. 4^h 123.

The observers' initials are those of Ralph Copeland and L. Becker.

Observations of the Biela Comet Meteors made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Greenwich Mean Solar Time Astronomical.		Number of Meteors seen by		Number per minute seen by		State of the sky.
1885.	h	F.	L.	F.	L.	
Nov. 27	$5\frac{1}{2}$	—	—	—	—	Cloudy; no meteors seen.
	6	—	—	—	—	Sky nearly cloudless; meteors seen in considerable numbers, and continued to be seen until the commencement of counting at $6^h\ 18^m$
	h m h m					
	6 18 to 6 37	626	—	32·9	—	
	6 37 6 47	—	200	—	20·0	
	6 37 6 49	449	—	37·4	—	
	6 49 6 58	—	100	—	11·1	
	6 51 6 59	109	—	13·6	—	
	6 58 7 4	10	—	1·7	—	
	7 5 7 15	—	13	—	1·3	Clouds appeared shortly before 7^h; sky nearly covered at 7^h.
	7 30	—	—	—	—	Several bright meteors seen through thin clouds.

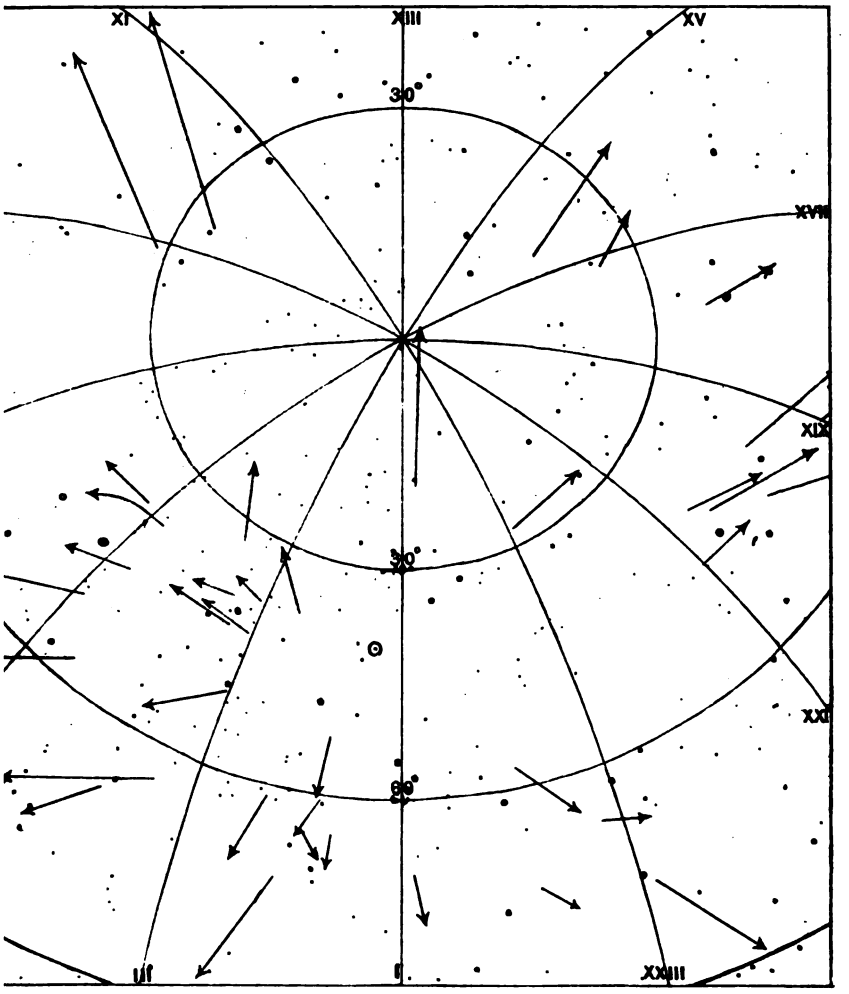
Greenwich Mean Solar Time Astronomical. 1885.			Number of Meteors seen by F.	Number of Meteors seen by L.	Number per minute seen by F.	Number per minute seen by L.	State of the sky.
	h m	h m					
Nov. 27	7 52	to 7 55	42	27	14·0	9·0	Partially cloudy; clouds variable in amount.
	7 55	8 2	91	101	13·0	14·4	" "
	8 2	8 7	66	37	13·2	7·4	" "
	8 12		—	—	—	—	Sky nearly covered; meteors still seen through small breaks and thin clouds.
	8 12	8 22	—	—	—	—	Meteors frequently seen through small breaks in the clouds.
	8 27	8 32		—	12·4	—	Seen chiefly in east and east-south-east.
	8 32	8 37	38	—	7·6	—	Seen chiefly in east and east-south-east; light clouds prevalent.
	8 37	8 52	—	—	—	—	Sky generally covered.
	8 57	9 2	29	—	5·8	—	Partially cloudy.
	9 2	9 7	19	—	3·8	—	" "
	9 7	9 12	30	—	6·0	—	" "
	9 12	9 17	32	43	6·4	8·6	Less cloud now.
	9 17	9 22	53	42	10·6	8·4	Few light clouds.
	9 22	9 27	55	54	11·0	10·8	" "
	9 27	9 32	36	43	7·2	8·6	Cloudy in north and north-west.

Greenwich Mean Solar Time Astronomical. 1885.			Number of Meteors seen by F.	L.	Number per m seen by F.	L.	State of the sky.
	h m	h m					
Nov. 27	9 32	to 9 37	40	47	8·0	9·4	Cloudy in north and north-west; nearly clear in south.
	9 37	9 42	28	—	5·6	—	,, ,, ,, ,,
	9 42	9 47	13	28	2·6	5·6	Partially cloudy.
	9 52	9 57	4	24	0·8	4·8	Cloudy in north.
	9 57	10 2	3	5	0·6	1·0	Cloudy.
	10 2	10 7	1	1	0·2	0·2	Nearly covered.
	10 7	10 12	1	0	0·2	0·0	Cloudy in south; clouds broken in north.
	10 12	10 17	8	3	1·6	0·6	Cloudy in north and south.
	10 17	10 22	11	26	2·2	5·2	Cloudy in north; clearer in south.
	10 22	10 27	13	16	2·6	3·2	Light cloud in north.
	10 27	10 32	10	12	2·0	2·4	Cloudy in north and east.
	10 32	10 37	6	7	1·2	1·4	Cloudy.
	10 37	10 42	1	1	0·2	0·2	,,
	10 42	10 47	9	8	1·8	1·6	,,
	47	10 52	11	6	2·2	1·2	,,
	10 52	10 57	5	1	1·0	0·2	,,
	10 57	11 2	3	4	0·6	0·8	,,

ROYAL OBSERVATORY, GREENWICH.

CHART OF METEOR TRACKS,

Observed by Mr. Nash on the night of 1885, November 27.



Radiant point shown thus ⊙

In the above counting the observers were placed back to back, Mr. Finch (F.) facing the northern portion of the sky, and Mr. Letchford (L.) the southern portion. The observers were careful that any meteors seen by both of them should be included in the count of one observer only.

Mr. Nash also reports that on the night of November 26 the sky was cloudy and the weather unfavourable for observation. On November 27 it remained cloudy till nearly 6^h; the sky then cleared somewhat suddenly, and meteors were found to be appearing in such numbers that steps were immediately taken by Messrs. Finch and Letchford to count them. Mr. Nash himself found that in and near the constellations *Cygnus* and *Lyra* alone, at $6^h\ 30^m$, and again at $6^h\ 50^m$, meteors were falling at the rate of thirty per minute; and deeming it impossible to make a complete and reliable description of the meteors then appearing, on account of their numbers, and fearing the probability of cloud intervening, he devoted his attention chiefly to the determination of the principal radiant point, which he found from numerous meteor paths of suitable brevity to be situated at R.A. 20° and Dec. N. 49°, referring to the period between 6^h and 7^h. After 7^h the sky was only clear at intervals, and forty tracks were then plotted on a prepared chart, principally from observations made between 8^h and $9^h\ 30^m$, confirming the preceding determination of the radiant. During the principal portion of the display (6^h to 7^h) the meteors were mainly white in colour and trained, unusually short in path and slow in motion, and the number of small meteors was remarkably large. After 9^h the numbers dropped off very perceptibly, and by 11^h, when the sky clouded up completely, they had fallen to two or three per minute. On November 28, with a clear sky during the greater part of the evening, a watch was maintained by one observer for nearly two hours, and ten meteors only were seen, of which four were apparently referable to the Biela Comet radiant.

The radiant point being situated near the centre of projection of the map, the meteor paths as plotted remain practically straight lines. In one case the path was actually observed to be curved.

Royal Observatory, Greenwich:
1885, *Dec.* 17.

Observations of the Meteor Shower of November 27, 1885, *made at the Glasgow Observatory.* By Prof. R. Grant, LL.D., F.R.S.

The meteors were first seen at the Glasgow Observatory a little before six o'clock in the evening. It was not long before it became evident that the number of meteors visible in a given time was gradually increasing. It was equally manifest that the position in the heavens from which the meteors appeared to diverge was situated in *Andromeda*, very near the stars γ and χ of that constellation. In general the meteors resembled in brightness stars of the 2nd and 3rd magnitudes, but a considerable number of them were equal to stars of the 1st magnitude, and every now and then there would burst forth a beautiful meteor rivalling in splendour the planet *Jupiter*. The colour of the meteors was generally white. In the case of the larger meteors, however, the light at the instant of breaking up of the meteor was characterised by a ruddy or orange hue. All the meteors except those in the immediate vicinity of the radiant point were in every instance accompanied by a luminous train, which, however, remained visible only two or three seconds. The abundance of meteoric apparitions seemed to have attained its maximum about $6^h\ 40^m$ G.M.T. Henceforth they gradually declined in numbers, and a haze coming on about 8 P.M. practically put an end to the wondrous display. Occasionally, however, a meteor might be seen traversing the atmosphere until about 10 P.M., when every trace of the phenomenon disappeared.

From a comparison of the apparent positions of three stationary meteors relatively to γ and χ *Andromedæ* I estimated the position of the radiant point to be very nearly R.A. 24°, Dec. N. 45° 30′. At the commencement of the shower Mr. H. Urquhart, one of the Observatory assistants, was detailed to count the meteors visible. The following are the results of his enumeration :—

G.M.T. h m	Number of Meteors visible per minute.	G.M.T. h m	Number of Meteors visible per minute.
6 3	54	7 00	60
6 8	56	7 5	74
6 13	58	7 10	44
6 18	67	7 15	32
6 23	50	7 20	33
6 30	64	7 25	23
6 35	80	7 30	23
6 40	80	7 35	38
6 45	50	7 40	24
6 50	48	7 45	23
6 55	70	7 50	23

Mr. Tannien, another assistant, made a partial enumeration of the meteors visible with the following results :—

G.M.T.	Number of Meteors visible per minute.	G.M.T.	Number of Meteors visible per minute.
h m		h m	
6 24	60	7 1	74
6 36	100	8 9	9

Mr. Urquhart continued counting without interruption the number of meteors visible from $5^h\ 58^m$ till $7^h\ 50^m$, embracing an interval of one hour and fifty-two minutes, and obtained 5,806 as the aggregate number of meteors visible. From what I have seen of such apparitions I am inclined to think that the number of meteors actually visible from the Glasgow Observatory during the interval to which I refer was at least four times as great as this number.

It has been my good fortune to have seen from this Observatory the great meteor shower of November 13, 1866, and also the meteor shower of November 27, 1872, in both instances under exceptionally favourable circumstances, and at the time of the recent shower I was naturally led to institute a comparison between the brilliant apparition then visible and the two preceding displays. The shower of the *Leonides* appeared to me to be beyond comparison the grandest of the three apparitions both in respect to the abundance and the magnitude of the meteors. On the other hand the recent apparition of the *Andromedes* offered a most striking resemblance in every respect to its brilliant predecessor of 1872.

The Biela Meteor Shower of November 27, 1885. By Prof. C. Pritchard, D.D., F.R.S.

Preparations were duly made at the University Observatory for recording what might occur in relation to the expected *Andromeda* meteors. Specially it was proposed to watch the neighbourhood of the radiant through a 4-inch telescope with a low power eye-piece, giving a field of about 50′ diameter.

The sky was generally fitful, never being wholly without cloud and frequently overcast. Slight rain fell at 9 P.M., and at intervals between that hour and 2 A.M.

Very many meteors were reported as flying about the sky by pedestrians in the city, as soon as it became sufficiently dark. The first count at the Observatory was made by the two assistants from 6 to 6.10 P.M., the one looking on the eastern sky and the other on the western. During this period sixty were counted,

but with the certainty that many had escaped notice. Their character was in general fleecy and small. Five of them were observed to pass over the square of *Pegasus* parallel to the diagonal joining *α Andromeda* to *α Pegasi*. The sky then became too cloudy to continue counting.

Between $6^h\ 34^m$ and $6^h\ 39^m$ G.M.T., when the sky had partially cleared, 102 were counted towards the eastern side and 149 on the western. The sky was then scrutinised through the 4-inch telescope in the neighbourhood of the presumed radiant. Not a single short meteor or evanescent star-like outburst was seen, though the sky was then at its clearest. Comparing the result with my recollection of the November meteors in 1866, the total absence of the expected phenomenon is worthy of notice.

Between $7^h\ 14^m$ and $7^h\ 19^m$ there were counted 104 on the eastern sky and 201 on the western. No meteors were seen apparently brighter than *Sirius*. Six bright meteors, of approximately the brightness of stars of the 1st magnitude, observed by Mr. Plummer between $6^h\ 53^m$ and $8^h\ 15^m$, gave the radiant near *ω Andromedæ* (R.A. 21°, N.P.D. 45°), which agreed with the general impression derived from the other meteors. Mr. Jenkins, from his observations, regarded the radiant as a little more easterly, viz. about R.A. 23°, and N.P.D. 46°. No further available observations were possible during the remainder of the night, owing to the general prevalence of clouds and rain.

University Observatory, Oxford:
1885, *Dec.* 10.

On the Meteoric Shower of November 27, 1885.

By Ralph Copeland, Ph.D.

On the night of November 27, 1878, Lord Lindsay (now Lord Crawford) and the writer watched at Dun Echt for the greater part of eight hours for any possible return of the Biela meteors of 1872. As far as the meteors in question were concerned, the immediate result was almost altogether negative, for scarcely a single shooting-star was seen which could be referred to a radiant in *Andromeda*. The conclusion, however, was obvious, that the meteors were not, by any means, distributed round the whole orbit of the lost comet. But by taking the comet's period at 6 years and 202 days, as given in the appendix to Herschel's *Outlines of Astronomy*, 11th edition, it became evident that in 1885, November 27, would fall only 40 days short of two periods elapsed since the grand display in 1872, and would afford the best chance that could occur during the remainder of

this century. This conclusion was communicated to the Royal Astronomical Society, along with a *résumé* of the above-mentioned observations.*

From the 22nd until the 26th inst. the nights at Dun Echt were unusually cloudy, so that no telescopic or other examination of the neighbourhood of the meteoric radiant was at all possible. At nightfall on the 27th a dense vault of clouds covered the whole heavens, excepting only an occasional clear streak on the horizon. It was at 5.45 G.M.T. that numerous bright meteors were first seen descending across this streak. But the clouds soon lifted and thinned rapidly, so that from $6^h\ 13^m$ to $6^h\ 21^m$ I was able to count 109 meteors which could be referred to a common source in the direction of *Andromeda*. They were all of one clearly-marked type, moving somewhat slowly, with well-defined heads, and of all degrees of brightness, from the 2nd magnitude down to the faintest streaks that the eye could distinguish. Occasionally one of fully the 1st magnitude would leave a train that lasted for four or five seconds. The meteors came, now singly, now in pairs, and not infrequently in bursts of five or six at a time.

By holding a direct-vision prism with the refracting angle in the direction of the paths of the meteors, and watching a part of the sky in which they were most numerous, it was not difficult to catch an occasional sight of their spectra. Of seven spectra seen in this way, all were of the same kind, consisting of a somewhat faint continuous spectrum, with one relatively very bright line. The position of this line was not determined, but it is probably not far from F. Indeed, the whole spectrum was rather like that of a bright planetary nebula superposed on a faint continuous spectrum.

Nineteen well-situated paths, noted between $7^h\ 17^m$ and $8^h\ 3^m$, gave a very definite radiant point in R.A. 25°·9 and N. Decl. 46°·4. An examination of this point and its surroundings with a very low power on a 6-inch telescope revealed nothing, while some little time was lost in the identification of the remarkable double nebula.—*Gen. Cat.*, Nos. 385–6.

In the mean time 700 meteors were counted towards the east, from $7^h\ 10^m$ to $7^h\ 30^m$ G.M.T.; while a member of my family numbered almost exactly 2,000 in the S.W. between $6^h\ 30^m$ and $7^h\ 30^m$, although in both cases the sky was often at least half clouded over. In half an hour, beginning at eight o'clock, favoured by a nearly clear sky, the last observer noted 864 meteors, again to the S.W. Shortly after nine o'clock, even while making every allowance for increasing cloud, it became most evident that the display was fast diminishing. About $10^h\ 40^m$ the canopy of cloud lifted a little towards the east for about ten minutes, but not a single meteor was seen to cross the

* See *Monthly Notices*, vol. xxxix., p. 520.

clear belt thus formed. Immediately afterwards heavy rain-clouds settled hopelessly down and concealed the sky for the rest of the night.

Dun Echt Observatory:
1885, *Nov.* 30.

The Great Shower of Andromedes, November 26, 27, 28, and 30, 1885. By W. F. Denning.

The nights of November 24 and 25 were overcast here.

On the evening of November 26 heavy rain fell before $8^h\ 30^m$, then the atmosphere cleared somewhat, and I counted 21 shooting stars in the ensuing 15 minutes. Of these, 19 were *Andromedes*. The sky then clouded again, but later on, through temporary breaks, I saw 42 additional meteors, including 41 *Andromedes*. I estimated that with a clear sky the hourly number visible for one observer was about 130. The radiant point was at $26°+44°$, but the observed tracks did not come precisely to a focus. It was necessary to adopt a radiant area of several degrees diameter in order to satisfy the directions. No observations were possible after $12^h\ 30^m$ on November 26; clouds and occasional storms interfered until daylight.

On November 27 the sky in the early evening was much involved in clouds and haze, but before the twilight had disappeared, and before any stars could be distinguished, I observed several fine *Andromedes* with their typical spark-trains and very slow motions. It was at once evident that since the preceding night the display had developed into one of great richness. As the sky grew darker the number of meteors rapidly increased, but the heavens continued to be so much involved in cloud that the real strength of the shower could not be adequately determined. I counted the meteors in intervals of five minutes as follow:—

		No. seen.	State of sky.
h m	h m		
5 10 to	5 15	33	Very cloudy and hazy. Only *Capella* and two or three other bright stars visible.
5 25	5 30	126	Sky very much overcast.
5 55	6 0	105	Sky more overcast, very few stars visible.
6 25	6 30	222	Clearer, but still hazy and the stars looking dim.

No regular observations could be obtained after $6^h\ 40^m$ owing to clouds and rain, which continued almost unabated

during the whole night. Before $9^h\ 15^m$, however, there occurred one or two transient breaks, and meteors were observed to be falling thickly, but only momentary glimpses were possible.

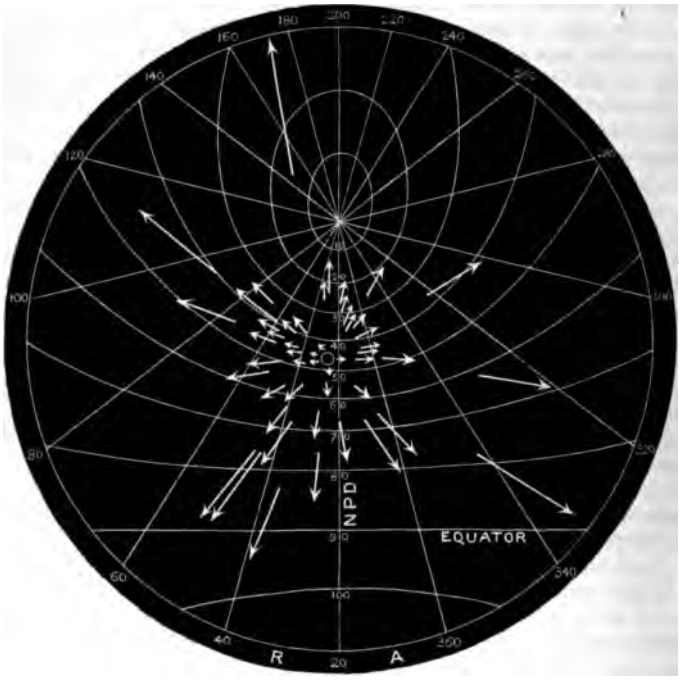
With a pefectly clear sky the number visible within the sphere commanded by one observer must have been equivalent to more than 5,000 per hour, judging from the richness of the phenomenon so imperfectly seen here between 6^h and $6^h\ 30^m$. The display was probably therefore quite equal to that of November 27, 1872. When clouds enforced the suspension of my observations, soon after $6^h\ 30^m$, the display was evidently intensifying; the meteors were beginning to fall in what may be described as intermittent volleys of 5, 7, or 10, and even more.

The radiant point was very inexact. In many cases I found that very accurately observed paths deviated several degrees from the mean. The area of radiation must have been fully 7° in diameter to accommodate the discordances in the flights. The centre was at $24° + 44°$, but I saw several very short paths from a point south of γ *Andromedæ*. I noted many of the meteors with the utmost care in order to assure myself of the diffuseness of radiation, and it was found impossible to get a sharply defined position. The contrary effect was indeed so obvious as to arrest the eye whenever simultaneous bursts of about six or seven meteors took place near the radiant. It was then seen that the collective flights were not symmetrical emanations from a central point. They rather appeared to be discharged in a loose, disjointed fashion from a comparatively large space on the N.W. region of γ *Andromedæ*, and just perhaps enveloping that star within its limits. With regard to this peculiarity the shower shows a departure from the rule I have found to obtain during the observation of minor streams. The tracks usually intersect almost at a point, and I believe that diffuse and uncertain radiation has a tendency to disappear altogether in cases where the observations are very exact. But every effort towards accuracy only exhibited the diffused radiation of the *Andromedes* in a more unmistakable manner, and proved it to be an inseparable feature of the shower's appearance.

Both on November 26 and 27 there was a tolerably large number of bright meteors. The very unfavourable weather here enabled me to make no comparative observations as to magnitude. It is certain that very few of the more minute *Andromedes* could be descried in a sky where stars below the 4th magnitude were hidden nearly the whole time. On November 26 I recorded several meteors as bright as *Jupiter*, and near to the maximum on November 27, some were seen brighter than *Venus*—many rivalled *Jupiter*. They invariably traversed short paths with very slow motions, and became extinct in evolved streams of yellowish sparks. Noting their visible aspects particularly, the conclusion seemed obvious that these meteors are formed of very

soft materials, which expand while incalescent, and are immediately crumbled and dissipated into exiguous dust. The resistance of the atmosphere upon some of the brightest of them appeared to be so effectual that they came almost to a standstill, and then disappeared with material and velocity alike spent.

On November 26 and 27 I noted about ten meteors of the class usually designated "sporadic." * Of these meteors, five were directed from a radiant point in *Cepheus* at 332°+58°. This has been observed before (though somewhat to the north of my position) by Dr. Konkoly on November 28, 1872, at 372°+63°, and by Mr. Sawyer on November 24, 1878, at 330°+63° (see *Monthly Notices*, vol. xl. p. 362, and *American Journal of Science and Arts*, vol. xvii, June 1879, Radiant No. 26). There is little doubt these are identical, the resemblance in position and epoch being very close.



Shower of *Andromedes*, 1885, Nov. 26 and 27. R.A. 25°, Dec. 44° N.
(W. F. Denning.)

The following are a few of the paths registered here on November 26 and 27 :—

* The term hardly seems to me a commendable one, though undoubtedly useful to conceal our ignorance of the contemporary streams supplying meteors unconformable to any special display that may be under observation.

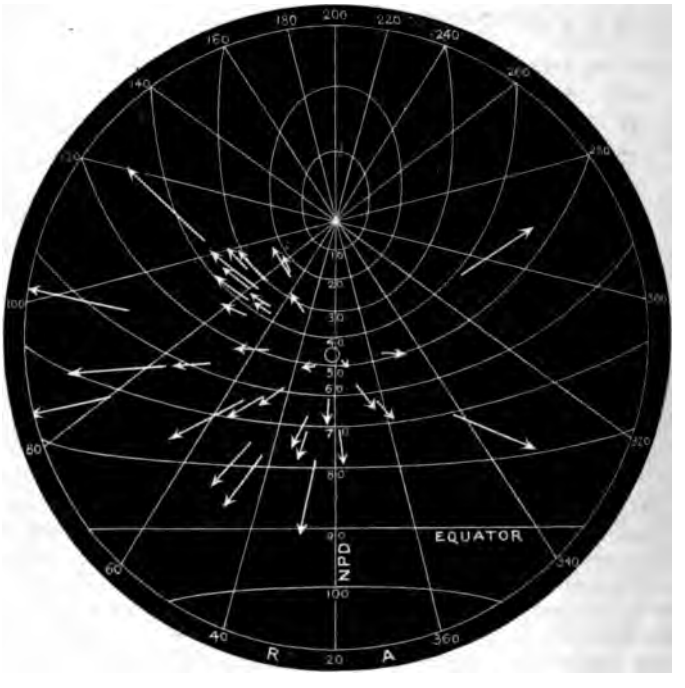
Date	Time	Mag.	Path Length. From		To		Notes.
	h m		°	°	°	°	
Nov. 26	8 42	4	48	+40	61	+36 ...11	V. slow, thick train.
26	8 51	1	26	67	26½	+76 ... 9	Very very slow, thick train.
26	9 47	1	94	51	112	46 ...13	Slow.
26	10 9	4	158	73½	177	60½...14½	V. slow, flash & train.
26	10 14	1	321	54	302	49 ...13	Slow, thick train.
26	10 33	1	46	13	52	2½...11	Very slow, train.
Nov. 27	5 19	1	15½	35	9	30½...17	,, ,,
27	5 22	♀	62	52	85	50½...14½	,, ,,
27	5 22	1	31	43	33½	42 ... 2	,, ,,
27	5 24	1	23	40½	21	39 ... 2	,, ,,
27	5 29	♀	20	25	18½	13 ...12	Slow, thick train.
27	5 31	1	3	42	347	38½...13	,, ,,
27	5 41	1	24	35½	22	31 ... 5	V. slow, thick train.
27	5 52	1	12	44	359½	42½... 9	,, ,,
27	6 10	1	5	46	354	45 ... 8	Slow, thick train.
27	6 12	1	7	20	1½	9 ...12	,,
27	6 17	1	351	64	326	66½...11	,,
27	6 17	1	5	60½	7½	66 ... 7	,,
27	6 34	1	10	54	356¼	59 ... 9	,,
27	9 1	1	20¼	44½	18	44½... 1½	V. slow, thick train.

On November 28 the sky was magnificently clear until the moon rose at about $11^h\ 30^m$. Watching for about four hours in the aggregate—between $6^h\ 15^m$–$8^h\ 30^m$ and $9^h\ 30^m$–$11^h\ 30^m$—I saw sixty-five shooting stars. The shower of *Andromedes* still continued though entirely shorn of its imposing character. I observed some fifty-five meteors from the radiant near γ *Andromedæ*, but they were nearly all extremely minute, and many of them would have passed unobserved but for the exceptional clearness of the atmosphere. About thirty were of the 5th or 6th magnitude, and I just caught several which I rated as 6½ magnitude. There was a marked absence of meteors from other showers during the evening, not more than about a dozen being recorded.

I expected to discover on the 28th some displacement capable of being defined in the position of the radiant, similar to that which affects the August *Perseids*, and which, to a greater extent, I observed in connection with the April *Lyrids* of the present year (*Nature*, No. 810, May 7, 1885, p. 5). In both these instances the change is in the direction of increasing R.A., but I find strong evidence amongst my results that the radiant of the *Andromedes* moves in the contrary direction. I append

several positions for comparison derived on the nights of November 26, 27, 28, and 30:—

	h m	h m	° °		h m	h m	° °
Nov. 26	8 38 to	8 57	26 + 44	Nov. 27	6 25 to	6 30	23 + 45
26	9 43	10 10	27 + 43	28	6 15	11 30	22 + 43½
26	11 50	11 59	26 + 43½	30	6 39	7 19	21 + 42½
27	5 0	6 0	24 + 43½				



Shower of *Andromedes*, 1885, Nov. 28. R.A. 22°, Dec. 43½° N.
(W. F. Denning.)

The position for the 28th was determined from thirty-five paths, and represents a much better-defined radiant than any of the others. The decidedly erratic character of the display on the 26th and 27th, as regards its focus of divergence, seemed to have disappeared, and the directions as I registered them on the 28th indicate a far more uniform point of intersection. My figures prove that this point is not stationary, but that it probably moves slowly to the westward.

On the 28th, at about 7^h 18^m, I witnessed a curious outburst of very faint *Andromedes* in the region N. of *α* and *β Aurigæ*. Five meteors were noted here (three of which were very nearly simultaneous) in less than two minutes, and these were closely succeeded by three others, all nearly in the same positions. It cannot be regarded as any other than a singular coincidence that eight shooting stars, belonging to a shower yielding at the time certainly not more than twenty meteors per hour for one observer, should appear in the same identical region within a few minutes. From the number of meteors actually counted during the evening there were only fourteen *Andromedes* per hour, but this is unquestionably below the real figures, for many meteors are lost by an observer during the moments his attention is withdrawn from the heavens to register the paths of those seen, and this is a detail of the work which requires to be done deliberately and cautiously, for ten observed meteor tracks exactly reproduced on the chart, are worth more than a hundred wild and hurried observations. The latter are useless, as leading to doubts and complications, whereas every accurate meteor-path possesses a certain value.

At about midnight on the 28th storm clouds came up from the west, and at an early hour on the morning of the 29th rain began falling and continued without intermission for some thirty-four hours. Thus I had no opportunity of seeing anything on the night of the 29th, though constantly on the alert for an opening. The evening of the 30th, however, came in clear, and at 5^h 30^m I began a close watch of the region of *Andromeda*. During the first hour I observed six shooting stars belonging to minor showers. There was no sign from the radiant in *Andromeda*, and I concluded the display had become exhausted. But at 6^h 39^m I saw a faint, slow meteor close to *θ Cassiopeiæ*, and directed straight from the radiant. Ten minutes later another was recorded passing $\frac{1}{2}°$ N. of the great nebula M 31, and between 7^h 5^m and 7^h 19^m I saw four others, all very slow, and with the usual trains and short paths. The radiant was well defined at $21° + 42\frac{1}{2}°$. Observations were continued until 10^h 16^m, when clouds overspread the sky. During my watch of $4\frac{1}{2}$ hours forty-one meteors were seen, of which ten certainly, and two others possibly, were *Andromedes*. It was the chief shower observed during the evening, though two others were equally well determined in respect of the points of radiation, viz. at—

$60° + 49°$	6 very swift meteors.
$41 + 39$	4 swift meteors.

I saw a bright 2nd magnitude meteor perfectly stationary at the former point at 8^h 32^m. It is coincident with one of the special instances of stationary radiation which I referred to

in detail in my paper in the *Monthly Notices*, December 1884, pp. 103–4.

The following night, December 1, was again clear, and watching the sky during the four hours between $5^h\ 45^m$ and $9^h\ 45^m$ I observed twenty-five shooting stars. The shower of *Andromedes* appeared to have become extinct; not a single path could be positively assigned to that radiant, though at $7^h\ 57^m$ I saw a very small, slow meteor crossing λ *Tauri* from the right direction, but it was so extremely faint that I regard it as uncertain. We may therefore fairly assume that on the night of December 1 the display had definitely ceased, and that, in the interval elapsed since the preceding night, the Earth had fully emerged from the stream.

On the night of December 4 observations were resumed, and forty-eight shooting stars seen in another four-hours' watch. There was no sign of any radiation from γ *Andromedæ*, though I registered two bright slow meteors with thick trains from the point $9°+33°$, which represents quite a distinct shower. (See *Monthly Notices*, Dec. 1884, p. 110, Radiant No. 9.)

On December 7 thirty shooting-stars were recorded in $3\frac{1}{2}$ hours. At $6^h\ 46^m$ I saw a very short, quick meteor, probably near a radiant almost identical with the *Andromedes*. I had seen two additional meteors of the same character, one on November 28, the other on November 30; and the combined paths indicate the radiant at $19°+43\frac{1}{2}°$. There is possibly a feeble stream of hyperbolic meteors encountering the Earth at nearly the same date and position as the meteors of Biela's Comet. Two of the paths referable to the former shower were so short, and presumably so close to their radiant, that there can hardly be a doubt of its existence. These were as follows:—

	h m	Mag.	Path.	
Nov. 30	7 2	3	$11°+40°$ to $7°+38\frac{1}{4}°$	Swift and short.
Dec. 7	6 46	3	$20+41$ $21+39$	V. quick, nearly stationary.

In the aggregate I saw 115 meteors on the four nights, November 28 and 30, December 1 and 4, not conformable to the true *Andromedes*, and from these I have derived the following radiant points which it may be useful to specify, as some of them will doubtless be reobserved during future watches for the *Andromedes*. I have not included my results for December 7, as the date is rather distant from the epoch of the great display:—

Ref. No.	Radiant. α δ	No. of Shooting Stars seen.	Notes.
1	$27°+71°$	4	Very slow, faint.
2	$41+39$	6	Swift, short.
3	$44+56$	8	Very slow, faint.
4	$60+49$	8	Very swift.

Ref. No.	Radiant. α δ	No. of Shooting Stars seen.	Notes.
	° °		
5	79+24	5	Slow.
6	105+34	8	Swift. Geminids.
7	110+25	4	Rather slow.
8	143+48½	6	Very swift. Streaks.
9	194+43	8	„ „

The latter was the best shower. It is situated about 4° N. of *Cor Caroli*, and supplied several fine long meteors. That this stream should have rendered itself conspicuous, despite its unfavourable position (during nearly the whole of my observations), closely verging the northern horizon, proves it to be one of more than ordinary significance.

I have recently noticed great disparity in the relative velocities of neighbouring showers. In the preceding table of radiants it will be observed the meteors from No. 3 at 44°+56° (near *η Persei*) were very slow, while those from No. 4 at 60°+49° (near *μ Persei*) were "very swift." It is certain that if the meteors of these different streams become visible at nearly the same heights in the atmosphere, they must be moving with vastly different velocities. It will be important to further watch these swift meteors from radiants so distantly removed from the apex of the Earth's way.

The recorded duration of the recent display of *Andromedes* over at least five nights is remarkable when we remember the short-lived character of the shower on November 27, 1872. On the nights of the 25th and 26th November of that year I found meteors scarce, and the fact was confirmed by Mr. Jackson at Tooting. On the 28th I saw no lingering traces of the shower, and Mr. Greg at Buntingford, and several observers at Hawkhurst, in Kent, were similarly unsuccessful (*Nature*, No. 162, December 5, 1872, p. 104). If these observations are conclusive, the observed duration of the phenomenon of 1872 appears to have been limited to a single night. It could not have formed a display of any importance on either of the two nights preceding or following the maximum, though a distinct shower of these *Andromedes* appears to have been witnessed in America as early as November 24, 1872. They were watched by Mr. T. Hadley and Professors Twining and Newton at Newhaven between $7^h\ 30^m$ and 12^h, when their numbers were recorded as forty per hour for one observer, and the radiant point, as estimated by Professor Newton, was 2° or 3° N. of *γ Andromedæ* (*B. A. Report* for 1873, p. 387). This shower had, however, on the 25th declined to one-third its richness, as determined on the 24th, so that the display may probably have been due (especially when we regard the negative results obtained in England on the nights immediately prior to the 27th) to a closely outlying system which could hardly have been connected with the main

stream, from the utter absence of intermediate meteors on November 26. I believe that for the return of the present year we must allow at least seven days' duration; for when I first detected it on the evening of the 26th it had already attained considerable intensity. And the relative numbers counted on the 26th and 28th prove the decline to have been more rapid than the rise, so that had observations been possible before moonrise on the early evenings of the 24th and 25th, the shower would have been duly recognised, gaining intensity each night until it afterwards culminated in the brilliant maximum of November 27.

Bristol: 1885, *Dec.* 8.

La grande pluie des étoiles filantes du 27 Novembre 1885.

By F. Denza.

(*Communicated by the Secretaries.*)

La pluie extraordinaire des étoiles filantes du 27 Novembre 1872 s'est renouvelée cette année le même jour et à peu près avec la même intensité. D'après les télégrammes et les relations que nous avons reçus en grand nombre jusqu'à présent, il résulte que le phénomène en question a été remarqué dans toute l'Italie depuis les Alpes jusqu'à l'extrémité de la Sicile, et qu'il se produisit partout sous les mêmes formes. Il commença à la tombée du jour. A Tarente à 5^h du soir les étoiles jaillissaient et filaient en lignes si compactes, qu'elles perçaient de temps en temps l'obscurité déjà avancée de la nuit. A Palerme quelques-uns de nos anciens élèves ingénieurs comptérent 4600 météores de 5^h 15 à 6^h 30. A cette heure la pluie météorique se manifestait en plusieurs autres endroits avec une abondance tout à fait surprenante.

Dans notre Observatoire on commença à explorer le ciel à 6^h du soir (temps moyen de Rome). Nous avons suivi la même méthode que je suivis en 1872; les observations actuelles peuvent en conséquence être comparables avec celles d'alors. Comme j'eus déjà plusieurs fois l'occasion d'exposer cette méthode, je crois à propos de l'omettre ici. Je me bornerai à rapporter les résultats obtenus de 15 en 15 minutes, et afin de mieux éclaircir ma relation, je vais donner ci-dessous un tableau dont la seconde colonne indique le nombre des observateurs chaque quart d'heure; et la troisième l'état de l'atmosphère en dixième de ciel libre. La quatrième colonne contient le nombre des météores réellement comptés, et la dernière le nombre supputé des étoiles, c.-à.-d. le nombre qu'on aurait dû avoir par conjecture si les observateurs eussent été toujours au nombre de quatre et que le ciel eût été toujours serein.

Durée de l'observation.	Nombre des observateurs.	Dixièmes de ciel découvert.	Nombre des météores. Observé.	Calculé.
6 0 à 6 15	2	10	2800	5600
6 15 6 30	2	10	3100	6200
6 30 6 45	$2\frac{1}{5}$	10	3400	6200
6 45 7 0	3	10	4500	6000
7 0 7 15	4	10	6200	6200
7 15 7 30	4	7	3500	5000
7 30 7 45	$3\frac{1}{2}$	7	3100	4900
7 45 8 0	4	7	3200	4600
8 0 8 15	4	7	3100	4400
8 15 8 30	4	7	1700	2400
8 30 8 45	4	6	1500	2500
8 45 9 0	4	5	1000	2000
9 0 9 15	4	5	800	1600
9 15 9 30	4	4	600	1500
9 30 9 45	4	4	500	1200
9 45 10 0	3	3	234	1000
10 0 10 8	4	3	312	1000
Heures ... 4 8			39546	62300

Le ciel fut obscurci à 10^h 8 par un épais brouillard, qui le déroba à nos yeux tout le reste de la nuit. Ailleurs aussi des noires vapeurs voilèrent le ciel à la même heure et même avant. Seulement dans quelques localités de montagne et du midi, où le ciel se conserva serein jusqu'à l'heure la plus reculée de la nuit on affirma d'un commun accord qu'à 11^h le phénomène était presque fini. Les observations que nous avons faites dans les deux soirées suivantes du 28 et du 29 nous conduisirent à un résultat identique.

En 1872 nous en eûmes 33000 dans l'espace de six heures; cette fois-ci, quoique les observateurs ne fussent pas toujours au nombre de quatre comme à cette époque, nous en avons compté 39000.

En 1872 l'abondance des étoiles atteignit son maximum entre 7^h 45 et 8^h 15; cette année au contraire le maximum avait eu déjà son commencement, quand le phénomène prit à paraître, ainsi que le prouvent les nombres calculés à Moncalieri dans les deux premières heures, lesquels sont presque constants. Beaucoup ont assuré que dès la nuit du 26 au 27 on vit une grande foule de météores sillonner les airs; ici le ciel était chargé. Les observations des régions orientales répandront plus de lumière sur ce sujet.

En 1872 nous étions toujours au nombre de quatre observateurs et nous comptâmes 18600 étoiles filantes pendant les deux heures proches du maximum, tandis que cette fois-ci dans

le même temps et presque toujours au nombre de deux ou de trois nous sommes parvenus à la chiffre imposante de 29500. Nous nous hâtons cependant de dire que toutes ces chiffres ne donnent qu'une estimation approximative de l'apparition, puisque pendant ces deux heures on ne comptait guère chaque météore, mais les groupes des étoiles seulement (et pas même tous), qui se succédaient presque sans interruption.

Par conséquent les résultats obtenus dans ce temps ne représentent que la cinquième ou la sixième partie, et peut-être sont-ils inférieurs au réel.

Je crois donc ne pas m'abuser en assurant que le nombre des étoiles apparues dans le temps de nos observations n'a pas été au-dessous de 150 à 160 mille. Le spectacle qui s'offrit à nos yeux pendant les deux premières heures du maximum était surprenant, et tel qu'on trouverait de la peine à le decrire. De toutes les parties du ciel il pleuvait des masses d'étoiles semblables à des nuages cosmiques qui se fondaient. Elles étaient suivies de traces lumineuses, et beaucoup de ces étoiles surpassaient celles de la première grandeur; quelques-unes même étaient de véritables bolides. La marche était en général haute, et la couleur prédominante était le rouge, tant à Moncalieri qu'ailleurs, occasionnée par les nombreuses vapeurs éparses dans l'atmosphère. Les météores qui se trouvaient le plus près des régions irradiantes étaient très-courts; aussi plusieurs n'étaient-ils que de points flamboyants par loi de prospective.

La plus grande partie jaillissait de la région même dont elles irradiaient en 1872, et laquelle se trouve entre *Cassiopée*, *Persée*, et *Andromède*.

On ne distinguait aucun centre secondaire comme dans les soirées ordinaires de la plus grande affluence.

Je mis tous mes soins à déterminer exclusivement la position du radiant, ce qui ne présentait aucune difficulté. Voilà de quelle manière je m'y pris. Je fixai attentivement sa position approximative et ensuite je traçai sur le papier le chemin de quelques-uns de ces météores qui se détachaient autour de ce point. J'achevai de cette façon 190 trajectoires, dont chacune à son tour en représente une infinité d'autres, qui suivaient le même chemin. En partageant ces trajectoires en trois groupes, j'ai obtenu les trois positions suivantes :—

		Radiant	
	h m	°	°
A	7 35	$\alpha = 22$	$\delta = +44$
	8 20	$\alpha = 26$	$\delta = +43$
	9 8	$\alpha = 28$	$\delta = +42$

Ces points sont compris entre ϕ et γ d'*Andromède*, et le troisiéme point est tout près de cette dernière étoile.

Mon savant collègue M. Schiaparelli eut pour résultat :—

	Radiant	
h m	°	°
A 6 35	$\alpha = 15$	$\delta = +45$
7 12	$\alpha = 18{\cdot}5$	$\delta = +44$
8 7	$\alpha = 23$	$\delta = +42$

En conclusion, la grande quantité de météores observés de ces jours est la même que l'ont vit en 1859 et en 1872; elle se présente avec un intervalle de 13 ans, qui correspond à la double période de la comète Biela-Gambart, avec laquelle cet essaim météorique a des relations immédiates.

De l'Observatoire de Moncalieri:
2 Déc. 1885.

Observations and Orbit of the Meteor Shower of 1885, *November* 27. By G. L. Tupman.

The meteors were first seen at about six o'clock, when they were falling very fast, three or four appearing simultaneously. Sitting at a north window my wife counted 300 meteors between $6^h\ 33^m$ and $6^h\ 45^m$, about one-third of which were bright, and many with trains which lasted a few seconds. The sky then clouded over. It cleared again about eight o'clock, when I went out and began to count, keeping the radiant point in the centre of the sphere of vision. With occasional interruptions from passing clouds, the following numbers were obtained:—

h m	h m			
8 13·0	to 8 20·0	...	100, or 14	per minute.
8 20·5	8 31·0	...	100, 10	,,
8 48·5	8 58·0	...	63, 7	,,
8 59·0	9 8·0	...	73, 8	,,
9 10·0	9 15·0	...	45, 9	,,

The sky then became permanently overcast, but at $10^h\ 30^m$, in an opening low down in the east, they were still falling fast.

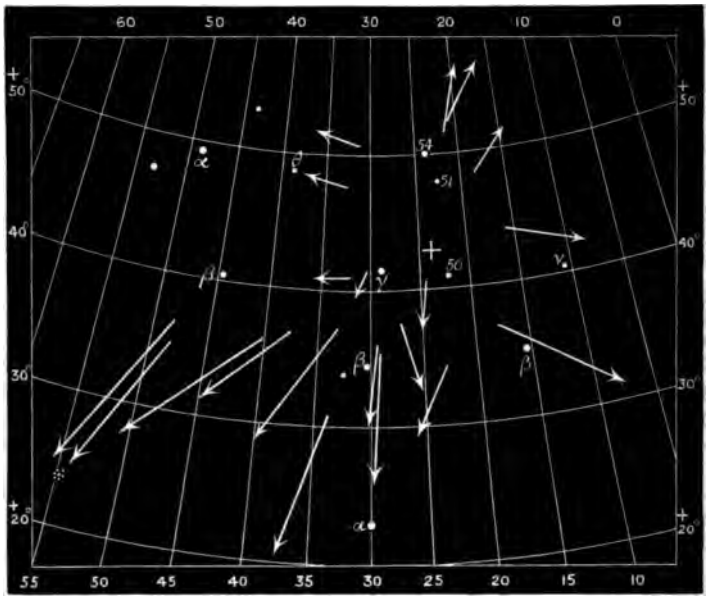
From $8^h\ 14^m$ to $8^h\ 31^m$, from the same window, my wife counted 150. In those seventeen minutes I had counted 200 in the open air. It is, therefore, reasonable to suppose that an observer in the open air, between $6^h\ 33^m$ and $6^h\ 45^m$, would have seen 400 meteors, or 33 per minute.

The brighter ones were of about the 1st magnitude—a few as bright as *Jupiter* or *Venus*. Many left streaks which endured two or three seconds. I only saw two or three brilliant enough to be called fireballs.

At first, instead of mapping tracks, I carefully watched for greatly foreshortened paths in the immediate neighbourhood of the radiant. About one half, perhaps, of them radiated from a

point midway between γ and 51 *Andromedæ*, in R.A. 27°, δ +44°; but nothing was more remarkable than the fact that the other half did *not* radiate from that point. The tracks of many characteristic *Andromedes*, when carried mentally backwards, did not pass within 10° of it.

Meteor Paths, 1885, Nov. 27, observed at Harrow.



The position of the *Cometary* Radiant is shown thus +.

During the latter part of the watch I mapped twenty tracks, as shown on the accompanying cut, selecting those which admitted of being pretty accurately reproduced as to direction and general position. The clouds interrupted this work, but the paths mapped are very instructive as to the nature of the radiation. Radiation from $22°\frac{1}{2}+45°\frac{1}{2}$ is sharply indicated. On the chart the theoretical radiant point proper to particles of Biela's Comet, using the orbit of 1852,* viz. 23°·5+43°·0, is indicated by a small cross. That is certainly not the point anyone would have fixed upon as the central position of the meteoric radiant. It falls, indeed, on the preceding limit of the radiant area. It is, perhaps, proper to mention that all the meteors moved slowly, in comparison with other showers. They were all white, except one which was a vivid red. One bright one stopped suddenly, became very much brighter; was stationary for about a second, then vanished.

On November 28, I watched for more than half an hour, about

* Corrected for Precession.

seven o'clock, with a perfectly clear sky, but only saw two *Andromedes*, no others.

The combination of the observations of this shower in 1872 and 1885 furnishes material for a calculation of the elements of the orbit without the necessity of assuming the mean distance to be the same as that of Biela's Comet. The only assumption I shall make is that, in the interval of thirteen years, the nucleus of the stream has made two complete revolutions.

In 1872, the maximum density of the shower was observed about November 27, 6^h G.M.T. On the present occasion the maximum would appear to have been about 5^h or 6^h G.M.T. The interval is 4748·0 mean solar days, and consequently the periodic time is 2374·0 days with very small error, corresponding to a mean distance of 3·4828.

The radius vector being common to both orbits (neglecting the dimensions of the Earth), the ratio of the orbital velocity of the meteors to that of the Earth is 1·30137 : 1.

The radiant points in the following table were determined with as much precision as is possible in such observations:—

	I. Nov. 26. 10^h	II. Nov. 27, 6^h	III. Nov. 27, 6^h	IV. Nov 28, 9^h	V. Nov. 30. 7^h
Denning ...	26°·7 + 43°·5	24° + 43°·5	23° + 45°	22° + 43°·5	21° + 42°·5
Tupman (9^h)		27 + 44	22·5 + 45·5		

These positions and the mean distance and ratio of velocities above give the following orbits. The time of perihelion passage is shown for comparison with the presumed time of perihelion passage of Biela's Comet:—

P.P.	I. Dec. 27^d·9	II. Dec. 27^d·8	III. Dec. 26^d·7	IV. Dec. 26^d·7	V. Dec. 27^d·0	Biela's Comet (A) Oct. 31 ?
Ω... ...	244°·9	245°·7	245°·7	246°·8	248°·8	246°·3
π... ...	112·2	111·1	109·2	108·2	107·3	109·6
i	13·1	13·0	13·6	12·5	11·6	12·6
e	·7556	·7532	·7508	·7470	·7432	·7559
q	·851	·860	·868	·881	·895	·861
$2a-q$ ...	6·114	6·106	6·097	6·085	6·071	6·191
Motion ...	D	D	D	D	D	D

Andromeda Meteors. By J. Rand Capron.

The display to which attention was drawn by circular from Dun Echt took place on the 27th, but earlier in the evening than was anticipated. It commenced soon after dusk and lasted till 9 P.M., when clouds and rain prevented further observations. Ten time records were taken at intervals at Guildown, and three other local ones have been communicated to me. At times the stars fell almost continuously, and occasionally three or four at

a time. As the result of actual countings of portions of the sky, the estimated general rate for all parts was found to be as follows:—

P.M.	Per minute.	P.M.	Per minute.
6	10	8·30	25
7·20	22	9·0	26
7·50	29		

A few of the observations when the shower was thickest gave forty to fifty per minute.

Except for a short interval about 7.30, there was always cloud and mist to some degree, so that the countings and estimates are possibly under the mark. The estimated proportion of large meteors was 1 in 10. These were white, with long yellow, or reddish-yellow trails, and three to four times the size and brightness of *Jupiter*. The intermediate ones in size were also white. The smaller stars often appeared of a bluish and some of a yellow, or yellow-red tint. A considerable proportion of the meteors were referred to the radiant point, but frequently they were scattered all over the sky, and not so easily traced. At intervals they seemed more numerous in particular quarters, notably E. and W., and two observers to different points would differ considerably in their countings. The numbers observed overhead did not seem larger than elsewhere. At 9 P.M. on the 28th three large ones were observed.

*Table of Observations of Andromeda Meteors, November 27, 1885, at Guildown, and two other places.**

Time. P.M.	State of weather.	Obs.	Time of Counting. m	No. observed.	Direction.
6	Partly thick	C.	5	25	N.
6	,, ...	L.	¼	5	N.
7	Much wind. Some seen through clouds				
7.20	Clear	W.	1	11	S. & W.
*7.30	,, ... (South Hill)	B¹.	10	74	N.E.
7.40	,, ...	P.	10	107	S. & W.
	10 larger ones in 67				
7.45	Clear	B².	1	25	N.
7.50	,, ...	P.	5	73	S.
7.50	Clouded	C.	5	12	N.
	Included several large ones				
8.0	Clearing, but part clouded ...	P.	10	68	N.E.
8.5	,, ,, ...	B².	1	25	E.
*8.15	,, ,, (Shere)	E. C.	1	20	?
8·30	,, ,, ...	P.	10	126	W.
9	,, ,, ...	C. & P.	5	65	W. & E.

Guildown: 1885, *Nov.* 28.

Meteor Shower connected with Biela's Comet. By the Rev. S. J. Perry, F.R.S.

The evening of November 27 was unfortunately cloudy at Stonyhurst, but it was cloudless until past midnight on the following day, and three observers kept a close watch for the meteors from 9.30 to 11.30, two of them remaining until 2 A.M. Fifty meteors were recorded, nine or ten of which radiated from the point R. 24°, δ +41°, and three other radiants in *Cygnus*, *Perseus*, and *Taurus*, were each fairly marked by four or five meteors. Those from *Andromeda* were of the 3rd or 4th magnitude, and were nearly all seen from 10.35 to 10.47, and from 12.20 to 12.27.

A note just to hand from Malta, gives the following account of the observations made of the meteor stream on the 27th, at St. Julian's Bay, by the Rev. J. Scoles, S.J., director of the Observatory.

"There was a fine display of meteors last night (27th), beginning as soon as dusk set in, attaining a maximum apparently about 7 P.M., and still continuing at 10 P.M. Radiant point very distinct in *Andromeda*, R.A. 21°, N.P.D. 46° approximately. Some of the trails very bright, and remaining visible in some cases for half a minute afterwards. Many were visible for a quarter of a minute. The uniformity of velocity in groups was very remarkable."

Stonyhurst Observatory:
1885, *Dec.* 8.

Notes on the Meteorites of November 27, 1885, as seen at East Tisted Rectory, Alton, Hants. By Rev. F. Howlett.

A few hours in anticipation of the time indicated in the notice so opportunely published by Dr. Copeland of Lord Crawford's Observatory at Dun Echt, the expected flight of meteorites so mysteriously connected with the orbit of the vanished comet of Biela was seen here for a limited time in great magnificence from about 6^h to $7^h\ 15^m$ on Friday evening, November 27, whilst the sky was fairly free from clouds.

The meteorites appeared in such multitudes, in greater or less frequency, that it was simply hopeless for any single observer to attempt correctly to count them, as they radiated from near γ *Andromedæ*, as was predicted, to all parts of the heavens, but chiefly, as it seemed to me, affecting the regions contiguous to *Pegasus*, *Cygnus*, and *Hercules*; though this impression may have been only illusory, and dependent upon the circumstance that the sky was generally clearer in those quarters than in others.

I should certainly say that, though perhaps on the whole not

so brilliant as were the *Leonids* of November 13–14, 1866, yet that they were decidedly more numerous. For whilst with the aid of one assistant, at the date just mentioned, I was enabled to estimate their apparition during the eight minutes (only) of the richest part of the shower, at 200 per minute, from $1^h\ 2^m$ to $1^h\ 10^m$ A.M. (see *Report of British Association* for 1867, p. 390), I should say that continuously almost, from 6^h to 7^h P.M. on Friday last, they were relatively fully 250 per minute.

A few that burst into view very close to γ *Andromedæ* appeared, as would necessarily be the case, almost if not quite stationary, but presenting sometimes a mass of luminous vapour fully half a degree sometimes in extent. All were of a white colour, and many left trains behind them for a few seconds of a ruddy and greenish hue. Unfortunately, after $7^h\ 15^m$ P.M., the sky became almost completely obscured by clouds and mist, though about 8 P.M. I could still perceive, through some partial breaks in the vapours, that the glorious pageant was still proceeding.

Watching for about a quarter of an hour on the following evening, November 28, with a perfectly clear sky from about 6^h to $6^h\ 15^m$ I only saw three meteors—of which the largest, equal in brilliancy to a star of the 1st magnitude, shot from near ϵ *Arietis* to a point midway between *Alpherat* and *Algenib*, quite another radiant therefore from that of November 27.

I imagine my estimate of the numbers seen on the day last mentioned will be questioned by some observers, but none the less should I maintain my opinion respecting them.

Meteoric Display, November 27, 1885.
By Colonel M. F. Ward.

The sky at the time had light clouds towards the south, but was intensely clear, and became suddenly alive with meteors falling to all points of the horizon from the small star χ *Andromedæ* (Proctor's map), with a slow motion, giving very much the idea of flakes of snow falling in a dead calm.

Some were very minute—barely visible—others as large as *Jupiter* or *Venus*. The latter travelled rapidly, leaving luminous streaks in their path, lasting in some cases more than half a minute—long enough to trace their direction to the above-named star.

Great numbers—and these of considerable size but of slow motion—came into view within a degree or two only of the horizon.

After 7.30 they diminished gradually in number. The sky clouded from 8 to 9.30, but the meteors were still seen in the intervals between the clouds.

At 9.30, sky again cloudless. Meteors still falling, though

in diminished numbers, on all sides. At midnight there were only occasional ones, and these chiefly in the west.

At first counting was quite impossible, but at 6.25 I was able to count, in one minute, between the N. and N.W. points, 104 meteors, my daughter counting 60 in the opposite quarter, and another 39 from the radiating point, in the same time (radiates).

At 10 P.M. I counted from that point 20, at 11 P.M. 7, and at midnight two meteors.

I have seen nothing like it since 1866.

Partenkirchen, Bavaria:

5.45 p.m. local time (44 m. fast of Greenwich). Lat. 47·30 N.; long. 11·5 E.

The Meteoric Shower as seen at Clapham on the night of November 27, 1885. By E. J. Spitta.

Observations were commenced at 6.10 P.M., and from that time until the clouds gathered, at 7 P.M., a careful watch was kept, and 660 meteors noted. As a matter of fact, I think the numbers should be 600 for the first 40 minutes, and 60 for the last 10, as the weather became thick at that time, and only the larger meteors could be seen and counted. Doing this, we have an average of about one in every four seconds.

Watch was again kept at 10.15, but few were then seen, and at 10.40 the clouds again gathered, and it commenced to rain.

Nearly all the meteors were small, about the 3rd or 4th magnitude, excepting a few which were larger, about equal to stars of the 1st magnitude, and two especially large ones, which rivalled *Jupiter* at opposition.

Speaking generally, very few left any train or sparks behind them; but, on the other hand, nearly all brightened up considerably before extinction.

With respect to colour: the heads were nearly all of a yellowish-white, but the larger type were pale blue. The two large ones before referred to as being so very bright, exhibited a decided bluish-white colour, like the magnesium balloons. These two left decided trains behind them, which had a tendency to redness, but they did not appear to last very long, although the meteors themselves travelled much slower than the rest.

No sound was heard of any kind during the whole time of observation, although such was carefully listened for.

The generality of the meteors did not last more than a second or a second and a half, but at the time of observation they were falling so quickly that it is difficult to make any definite statement.

Most of them indicated a starting-point somewhere near γ *Andromedæ*, but others a point nearer *Algol*, or 51 *Andromedæ*.

The path described in arc of most of the meteors was very

short; indeed, a great many appeared as if they were coming directly at the observer. But still a great many extended long lengths, some to the south, more to the east, but the most by far towards the north. Of the two large ones before referred to, one passed southwards, the other in a direction north-eastwards.

For the purpose of further investigation, I turned the 10-inch reflector on to a point near γ *Andromedæ*, a friend continuing the counting meanwhile, and I was lucky enough to see a small meteor cross the field in a few moments. Its passage appeared extremely rapid. Its colour was bluish-white rather than yellow, and it left not a vestige of a tail or a solitary spark.

The comparison of the shower this year and of that in 1872 may be said to be as follows:—

The meteors are much the same in size; if anything a trifle smaller.

The absence of tails of any great length in either years. The colours exhibited nearly similar.

Neither in this year nor in 1872 did the meteors extend to any great lengths of arc.

The numbers counted about the same, and the shower, comparatively speaking, over by 10.30, or thereabouts.

The radiant point seemed to extend itself towards *Cassiopeia* and *Perseus* as the evening wore on.

Ivy House, Clapham Common, S.W.:
1885, *Dec.* 10.

Addition to the Ephemeris for Physical Observations of Mars, 1886.

By A. Marth.

The Zero-Meridian, adopted in the ephemeris on p. 29 ff. will pass the centre of the disc of *Mars* at the following Greenwich Mean Times:—

1886	h m	1886	h m	1886	h m
Jan. 7	2 30·8	Jan. 19	10 5·9	Jan. 31	17 33·6
8	3 9·0	20	10 43·5	Feb. 1	18 10·5
9	3 47·1	21	11 21·1	2	18 47·3
10	4 25·2	22	11 58·6	3	19 24·1
11	5 3·2	23	12 36·1	4	20 0·8
12	5 41·2	24	13 13·5	5	20 37·5
13	6 19·2	25	13 50·8	6	21 14·1
14	6 57·1	26	14 28·1	7	21 50·7
15	7 35·0	27	15 5·3	8	22 27·2
16	8 12·8	28	15 42·4	9	23 3·6
17	8 50·6	29	16 19·5	10	23 40·0
18	9 28·3	30	16 56·6	12	0 16·4

1886	h	m	1886	h	m	1886	h	m
Feb. 13	0	52·7	Mar. 27	1	21·1	May 8	2	54·6
14	1	28·9	28	1	57·3	9	3	33·1
15	2	5·0	29	2	33·6	10	4	11·6
16	2	41·1	30	3	10·0	11	4	50·2
17	3	17·2	31	3	46·4	12	5	28·8
18	3	53·2	Apr. 1	4	22·9	13	6	7·4
19	4	29·2	2	4	59·4	14	6	46·1
20	5	5·1	3	5	36·0	15	7	24·8
21	5	41·0	4	6	12·7	16	8	3·6
22	6	16·8	5	6	49·4	17	8	42·4
23	6	52·6	6	7	26·2	18	9	21·2
24	7	28·4	7	8	3·0	19	10	0·1
25	8	4·2	8	8	39·9	20	10	39·0
26	8	39·9	9	9	16·9	21	11	17·9
27	9	15·6	10	9	53·9	22	11	56·9
28	9	51·2	11	10	31·0	23	12	35·9
Mar. 1	10	26·8	12	11	8·1	24	13	14·9
2	11	2·4	13	11	45·3	25	13	54·0
3	11	38·0	14	12	22·6	26	14	33·1
4	12	13·6	15	12	59·9	27	15	12·2
5	12	49·2	16	13	37·3	28	15	51·3
6	13	24·8	17	14	14·8	29	16	30·5
7	14	0·4	18	14	52·3	30	17	9·7
8	14	36·0	19	15	29·9	31	17	48·9
9	15	11·6	20	16	7·5	June 1	18	28·2
10	15	47·2	21	16	45·2	2	19	7·5
11	16	22·8	22	17	22·9	3	19	46·8
12	16	58·5	23	18	0·6	4	20	26·1
13	17	34·2	24	18	38·4	5	21	5·5
14	18	9·9	25	19	16·3	6	21	44·9
15	18	45·6	26	19	54·2	7	22	24·3
16	19	21·3	27	20	32·2	8	23	3·7
17	19	57·1	28	21	10·2	9	23	43·2
18	20	32·9	29	21	48·3	11	0	22·7
19	21	8·8	30	22	26·5	12	1	2·2
20	21	44·7	May 1	23	4·7	13	1	41·7
21	22	20·6	2	23	42·9	14	2	21·3
22	22	56·6	4	0	31·1	15	3	0·9
23	23	32·7	5	0	59·4	16	3	40·5
25	0	8·8	6	1	37·8	17	4	20·1
26	0	44·9	7	2	16·2	18	4	59·8

1886	h m	1886	h m	1886	h m
June 19	5 40·4	June 23	8 18·2	June 27	10 57·3
20	6 19·1	24	8 57·9	28	11 37·1
21	6 58·8	25	9 37·7	29	12 16·9
22	7 38·5	26	10 17·5	30	12 56·8

Ephemeris of the Satellites of Uranus, 1886. By A. Marth.

P, angle of position of the minor axes of the apparent orbits.
a, b, major and minor semi-axes of the apparent orbits.
$u-U$, longitudes of the satellites in their orbits, reckoned from the points which are in superior conjunction with the planet or in opposition to the Earth.
$U+180°$, planetocentric longitude of the Earth reckoned in the assumed plane of the orbits from the ascending node on the celestial equator.
B, planetocentric latitude of the Earth above the plane of the orbits, the ascending node N and inclination J to the equator of 1880·0 are assumed to have the values

$$N = 165°{\cdot}770, \qquad J = 75°{\cdot}210.$$

		Ariel.					*Umbriel.*			
Greenwich Noon	P	a_1	b_1	u_1-U	Diff.		a_2	b_2	u_2-U	Diff.
1886	°	″	″	°	c		″	″	°	c
Jan. 13	284·96	14·67	+ 5·35	50·41	1428·47		20·43	+ 7·46	161·93	868·75
23	284·97	14·80	5·39	38·88	·45		20·62	7·50	310·68	·73
Feb. 2	284·99	14·92	5·40	27·33	·42		20·79	7·52	99·41	·72
12	285·01	15·03	5·38	15·75	·39		20·94	7·49	248·13	·69
22	·04	15·12	5·34	4·14	·36		21·07	7·44	36·82	·67
Mar. 4	·07	15·19	5·27	352·50	·34		21·17	7·35	185·49	·65
14	·11	15·24	5·19	340·84	·31		21·23	7·23	334·14	·63
24	285·14	15·26	+ 5·09	329·15	·29		21·26	+ 7·09	122·47	·62
April 3	·17	15·26	4·98	317·44	·26		21·25	6·94	271·39	·61
13	·20	15·22	4·87	305·70	·25		21·21	6·78	60·00	·60
23	·22	15·17	4·75	293·95	·23		21·13	6·62	208·60	·60
May 3	·24	15·09	4·64	282·18	·23		21·02	6·47	357·20	·60
13	·26	14·99	4·55	270·41	·22		20·88	6·33	145·80	·60
23	·27	14·88	4·46	258·63	1428·22		20·72	6·22	294·40	868·60
June 2	285·27	14·75	+ 4·40	246·85			20·55	+ 6·13	83·00	

	Titania.				*Oberon.*				
	a_3	b_3	u_3-U	Diff.	a_4	b_4	u_4-U	U	B
1886	"	"	°	°	"	"	°	°	°
Jan. 13	33·51	+12·23	181·70	413·53	44·82	+16·36	76·22	3·28	+21·41
23	33·81	12·31	235·23	·52	45·22	16·46	343·62	3·30	21·35
Feb. 2	34·10	12·33	288·75	·50	45·60	16·49	251·01	3·33	21·20
12	34·35	12·29	342·25	·49	45·93	16·44	158·39	3·37	20·96
22	34·56	12·20	35·74	·48	46·21	16·31	65·75	3·42	20·66
Mar. 4	34·72	12·05	89·22	·46	46·43	16·11	333·09	3·48	20·30
14	34·83	11·86	142·68	·45	46·58	15·86	240·43	3·54	19·90
24	34·87	+11·63	196·13	·45	46·64	+15·55	147·76	3·60	+19·48
April 3	34·86	11·38	249·58	·44	46·62	15·22	55·09	3·67	19·05
13	34·79	11·12	303·02	·44	46·52	14·87	322·42	3·73	18·64
23	34·66	10·86	356·46	·45	46·34	14·52	229·75	3·78	18·26
May 3	34·47	10·61	49·91	·45	46·10	14·19	137·09	3·83	17·93
13	34·25	10·39	103·36	·46	45·80	13·89	44·43	3·86	17·66
23	33·99	10·20	156·82	413·46	45·46	13·64	311·78	3·88	17·46
June 2	33·71	+10·05	210·28		45·08	+13·44	219·14	3·89	+17·34

The values of P, a, b, and $u-U$ are to be interpolated for the times for which the apparent positions of the satellites are required, the equation of light being already taken into account. The position-angles p and distances s are then found by means of the equations

$$s \sin (p-P) = a \sin (u-U),$$
$$s \cos (p-P) = b \cos (u-U).$$

The satellites move in the direction of *in*creasing position-angles, and will be at their greatest elongations, and at their conjunctions with the centre of the planet, at the following Greenwich Mean Times:—

Ariel.

1886	N.	S.		N.	S.		N.	S.
$p=$	P+90°	P−90°		h	h		h	h
	h	h	Mar. 7	4·9	8 11·2	Apr. 11	11·8	12 18·0
Feb. 2	10·5	3 16·8	9	17·4	10 23·6	14	0·2	15 6·5
4	23·0	6 5·3	12	5·8	13 12·1	16	12·7	17 19·0
7	11·5	8 17·7	14	18·3	16 0·6	19	1·2	20 7·5
10	0·0	11 6·2	17	6·8	18 13·1	21	13·7	22 20·0
12	12·5	13 18·7	19	19·3	21 1·6	24	6·2	25 8·5
15	1·0	16 7·2	22	7·8	23 14·1	26	14·7	27 21·0
17	13·4	18 19·7	24	20·3	26 2·5	29	3·2	30 9·5
20	1·9	21 8·2	27	8·8	28 15·0	May 1	15·7	2 22·0
22	14·4	23 20·7	29	21·3	31 3·5	4	4·2	5 10·4
25	2·9	26 9·2	Apr. 1	9·8	2 16·0	6	16·7	7 22·9
27	15·4	28 21·6	3	22·3	5 4·5	9	4·2	10 11·4
Mar. 2	3·9	3 10·1	6	10·8	7 17·0	11	17·7	12 23·9
4	16·4	5 22·6	8	23·3	10 5·5	14	6·2	15 12·4

Umbriel.

1886.	N. h	S. h	N. h	S. h	N. h	S. h
Feb. 6	0·9	8 2·6	Mar. 11 4·5	13 6·3	Apr. 13 8·3	15 10·0
10	4·3	12 6·0	15 8·0	17 9·7	17 11·8	19 13·5
14	7·8	16 9·5	19 11·5	21 13·2	21 15·2	23 17·0
18	11·2	20 13·0	23 14·9	25 16·7	25 18·7	27 20·4
22	14·7	24 16·4	27 18·4	29 20·1	29 22·2	M. 1 23·9
26	18·1	28 19·9	31 21·9	A. 2 23·6	May 4 1·6	6 3·4
Mar. 2	21·6	4 23·3	Apr. 5 1·3	7 3·1	8 5·1	10 6·8
7	1·1	9 2·8	9 4·8	11 6·6	12 8·6	14 10·3

Titania.

1886 $p=$	Super. Conj. P h	N. Elong. P+90° h	Infer. Conj. P+180° h	S. Elong P−90° h
Jan. 26	0·4	Jan. 28 4·6	Jan. 30 8·9	Feb. 1 13·1
Feb. 3	17·4	Feb. 5 21·6	Feb. 8 1·8	10 6·1
12	10·3	14 14·5	16 18·8	18 23·0
21	3·3	23 7·5	25 11·7	27 16·0
Mar. 1	20·2	Mar. 4 0·5	Mar. 6 4·7	Mar. 8 8·9
10	13·2	12 17 4	14 21·7	17 1·9
19	6·1	21 10·4	23 14·6	25 18·9
27	23·1	30 3·4	Apr. 1 7·6	Apr. 3 11·9
Apr. 5	16·1	Apr. 7 20·3	10 0·6	12 4·8
14	9·1	16 13·3	18 17·6	20 21·8
23	2·1	25 6·3	27 10·5	29 14·8
May 1	19·0	May 3 23·3	May 6 3·5	May 8 7·8
10	12·0	12 16·2	14 20·5	17 0·7
19	5·0	21 9·2	23 13·5	25 17·7
27	21·9	30 2·2	June 1 6·4	June 3 10·7

Oberon.

1886	Super. Conj. h	N. Elong. h	Infer. Conj. h	S. Elong. h
Jan. 23	14·7	Jan. 26 23·5	Jan. 30 8·3	Feb. 2 17·0
Feb. 6	1·8	Feb. 9 10·6	Feb. 12 19·4	16 4·2
19	13·0	22 21·8	26 6·6	Mar. 1 15·4
Mar. 5	0·2	Mar. 8 8·9	Mar. 11 17·7	15 2·5
18	11·3	21 20·1	25 4·9	28 13·7
31	22·5	Apr. 4 7·3	Apr. 7 16·1	Apr. 11 0·9
Apr. 14	9·7	17 18·5	21 3·3	24 12·1
27	20·9	May 1 5·7	May 4 14·5	May 7 23·3
May 11	8·1	14 16·9	18 1·7	21 10·5
24	19·8	28 4·1	31 12·9	June 3 21·7

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVI. JANUARY 8, 1886. No. 3

EDWIN DUNKIN, F.R.S., President, in the Chair.

J. E. Evans, Principal of the Training College, Dindigal, Madras;
George Ford, B.A., Christ's College, Cambridge;
Jacob Gerhard Lohse, 68, Falsgrave Road, Scarborough;
William Irving Page, F.R.G.S., Wimbledon Common;
Captain George Parker, F.R.G.S., A.I.C.E., M.R.A.S., H.M.'s Indian Marine, Kurrachee, India;
Julien Tripplin, Belle Vue, Heathfield Gardens, Chiswick, W.;
E. L. Trouvelot, Observatoire d'Astronomie Physique, Meudon, Seine-et-Oise, France;

were balloted for and duly elected Fellows of the Society.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1885, *and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.* By E. J. Stone, M.A., F.R.S.

The present paper contains the Right Ascensions and North Polar Distances of the Moon as deduced from the observations made at the Radcliffe Observatory during the year 1885. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions:—

(1) That the mean times, found in the usual way from the sidereal times at mean noon given in the *Nautical Almanac*, were *not* changed in 1864.

(2) That the mean times *were* changed in 1864, in accordance with the views which I have explained in papers already communicated to the Society.

For facilities for an accurate comparison between Hansen's Lunar Tables and observations we are now indebted to the places published in the *Connaissance des Temps*.

TABLE I.

Radcliffe Observations of the Moon, 1885.

Corr. to be subtracted from M.T. computed directly from Sid. Time at Mean Noon. from *N.A.*	Observer.	Day, 1885.	Observed R.A.	Secs. of Hansen's R.A.	Hans.—Obs. *Uncorrected* for Error in Time.	Corr. due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.	Observed N.P.D.	Secs. of Hansen's N.P.D.	Hans.—Obs. *Uncorrected* for Error in Time.	Corr. due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.
s			h m s	s	s	s	s	° ′ ″	″	″	″	″
31·28	F.B.	Jan.	12 22 57·55	58·79	+1·24	−1·06	+0·18	92 41 41·78	44·98	+3·20	−5·27	−2·07
31·28	R.		14 2 28·06	28·97	+0·91	−1·04	−0·13	100 18 24·99	27·67	+2·68	−4·23	−1·55
31·34	R.	Jan. 23	1 54 17·27	17·95	+0·68	−1·15	−0·47	80 25 22·40	20·37	−2·03	+4·83	+2·80
31·35	F.B.	24	...	...	...	...	...	76 51 21·77	19·65	−2·12	+4·09	+1·07
31·39	W.	Feb. 4	13 42 27·27	28·45	+1·18	−1·07	+0·11	98 38 24·84	29·06	+4·22	−4·61	−0·39
31·40	R.	5	14 32 53·29	54·19	+0·90	−1·06	−0·16	102 0 10·22	11·91	+1·69	−3·88	−2·19
31·46	F.B.	Feb. 21	3 30 54·23	54·86	+0·63	−1·23	−0·60	75 1 13·72	12·17	−1·55	+3·34	+1·79
31·47	R.	23	5 32 34·92	35·37	+0·45	−1·31	−0·86	71 48 56·41	54·87	−1·54	+0·56	−0·98
31·47	W.	24	6 35 28·49	28·95	+0·46	−1·32	−0·86	72 0 54·31	56·87	+2·56	−1·06	+1·50
31·48	R.	27	9 39 32·29	32·83	+0·54	−1·23	−0·69	79 37 31·72	36·07	+4·35	−4·91	−0·56
31·51	F.B.	Mar. 6	15 52 47·29	48·57	+1·28	−1·09	+0·19	105 50 33·05	35·34	+2·29	−2·51	−0·22
31·58	R.	Mar. 23	6 15 50·01	50·28	+0·27	−1·30	−1·03	71 53 6·41	8·23	+1·82	−0·54	+1·28
31·60	R.	27	10 13 19·95	20·50	+0·55	−1·18	−0·63	82 0 38·58	42·16	+3·58	−5·17	−1·59
31·60	F.B.	28	11 8 17·72	18·40	+0·68	−1·15	−0·47	86 14 17·33	19·03	+1·70	−5·53	−3·83

Corr. to be subtracted from M.T. computed directly from Sid. Time at Mean Noon. from *N.A.*	Observer.	Day, 1885.	Observed R.A.	Secs. of Hansen's R.A.	Hans.—Obs. *Uncorrected* for Error in Time.	Corr. due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.	Observed N.P.D.	Secs. of Hansen's N.P.D.	Hans.—Obs. *Uncorrected.* for Error in Time.	Corr. due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.
s			h m s	s	s	s	s	° ′ ″	″	″	″	″
31·61	R.	Mar. 30	12 54 27·71	28·60	+0·89	−1·11	−0·22	94 51 39·57	43·90	+4·33	−5·25	−0·92
31·62	F.B.	Apr. 3	16 22 7·82	9·15	+1·33	−1·10	+0·23	106 49 33·28	36·34	+3·06	−1·96	+1·10
31·70	F.B.	Apr. 22	8 58 58·77	59·67	+0·90	−1·22	−0·32	77 6 36·53	39·12	+2·59	−4·14	−1·55
31·71	F.B.	25	11 42 46·40	47·33	+0·93	−1·11	−0·18	89 0 25·26	30·21	+4·95	−5·50	−0·55
31·72	R.	27	13 26 1·22	2·07	+0·85	−1·10	−0·25	97 17 18·44	22·55	+4·11	−4·92	−0·81
31·72	W.	28	14 17 23·76	24·72	+0·96	−1·10	−0·14	100 53 26·56	29·60	+3·04	−4·26	−1·22
31·73	F.B.	29	15 9 0·14	1·39	+1·25	−1·10	+0·15	103 54 12·71	16·30	+3·59	−3·42	+0·17
31·74	R.	May 1	16 52 58·89	59·91	+1·02	−1·11	−0·09	107 40 20·70	24·08	+3·38	−1·34	+2·04
31·82	F.B.	May 23	12 18 49·32	50·24	+0·92	−1·09	−0·17	91 50 31·61	35·72	+4·11	−5·42	−1·31
31·84	F.B.	27	15 42 19·67	21·03	+1·36	−1·10	+0·26	105 29 1·61	3·84	+2·23	−2·84	−0·61
31·84	W.	28	16 34 4·20	5·50	+1·30	−1·11	+0·19	107 17 33·11	35·57	+2·46	−1·79	+0·67
31·85	R.	29	17 26 2·29	3·36	+1·07	−1·11	−0·04	108 15 38·53	39·41	+0·88	−0·68	+0·20
31·86	W.	June 1	19 59 47·59	48·81	+1·22	−1·08	+0·14	106 0 53·39	53·90	+0·51	+2·51	+3·02
31·86	F.B.	2	20 49 33·15	34·63	+1·48	−1·06	+0·42	103 42 42·59	40·03	−2·56	+3·39	+0·83
31·96	R.	June 26	18 0 42·18	43·23	+1·05	−1·11	−0·06	108 27 22·15	21·58	−0·57	+0·02	−0·55
31·96	F.B.	27	18 52 13·31	14·60	+1·29	−1·10	+0·19	108 1 15·31	12·61	−2·70	+1·11	−1·59
31·98	W.	July 1	22 11 14·97	16·23	+1·26	−1·04	+0·22	98 45 15·72	12·83	−2·89	+4·51	+1·62

Corr. to be subtracted from M.T. computed directly from Sid. Time at Mean Noon. from *N.A.*	Observer.	Day, 1885.	Observed R.A.	Secs. of Hansen's R.A.	Hans.—Obs. *Uncorrected* for Error in Time.	Corr due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.	Observed N.P.D.	Secs. of Hansen's N.P.D.	Hans.—Obs. *Uncorrected* for Error in Time.	Corr. due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.
s			h m s	s	s	s	s	° ′ ″	″	″	″	″
32·06	R.	July 22	16 52 30·81	31·95	+1·14	−1·11	+0·03	107 34 12·86	13·71	+0·85	−1·52	−0·67
32·07	F.B.	23	17 44 2·67	3·90	+1·23	−1·11	+0·12	108 19 9·57	10·92	+1·35	−0·41	+0·94
32·07	R.	24	18 35 33·36	34·18	+0·82	−1·11	−0·29	108 12 30·66	29·75	−0·91	+0·70	−0·21
32·08	F.B.	25	19 26 42·98	44·24	+1·26	−1·10	+0·16	107 14 57·54	55·17	−2·37	+1·77	−0·60
32·08	F.B.	26	20 17 16·68	17·77	+1·09	−1·08	+0·01	105 29 31·33	29·86	−1·47	+2·76	+1·29
32·18	W.	Aug. 19	17 26 18·49	19·79	+1·30	−1·12	+0·18	108 0 49·10	50·71	+1·61	−0·84	+0·77
32·18	W.	21	19 9 7·97	9·06	+1·09	−1·10	−0·01	107 34 59·41	59·18	−0·23	+1·38	+1·15
32·19	F.B.	22	19 59 55·80	56·91	+1·11	−1·09	+0·02	106 7 28·04	25·71	−2·33	+2·40	+0·07
32·20	W.	24	21 39 44·93	46·01	+1·08	−1·07	+0·01	101 2 58·81	54·20	−4·61	+4·10	−0·51
32·20	F.B.	25	22 28 54·94	56·52	+1·58	−1·06	+0·52	97 38 56·83	52·39	−4·44	+4·71	+0·27
32·30	R.	Sept. 18	19 40 40·96	41·99	+1·03	−1·10	−0·07	106 43 13·90	11·82	−2·08	+2·02	−0·06
32·30	F.B.	19	20 31 2·19	3·20	+1·01	−1·09	−0·08	104 47 62·35	59·85	−2·50	+2·98	+0·48
32·31	R.	21	22 10 16·92	17·72	+0·80	−1·07	−0·27	98 58 31·26	27·76	−3·50	+4·52	+1·02
32·32	R.	25	1 31 56·86	58·00	+1·14	−1·15	−0·01	83 4 41·12	36·48	−4·64	+5·18	+0·54
32·34	W.	30	6 21 13·30	14·41	+1·11	−1·33	−0·22	71 50 33·78	34·74	+0·96	−0·41	+0·55

Corr. to be subtracted from M.T. computed directly from Sid. Time at Mean Moon. from *N.A.*	Observer.	Day, 1885.	Observed R.A.	Secs. of Hansen's R.A.	Hans.—Obs. *Uncorrected* for Error in Time.	Corr. due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.	Observed N.P.D.	Secs. of Hansen's N.P.D.	Hans.—Obs. *Uncorrected* for Error in Time.	Corr. due to Error in Time.	Hans.—Obs. *Corrected* for Error in Time.
s			h m s	s	s	s	s	° ′ ″	″	″	″	″
32·40	R.	Oct. 15	19 19 59·04	59·99	+0·95	−1·11	−0·16	107 20 49·33	48·86	−0·47	+1·59	+1·12
32·41	R.	16	20 10 31·71	32·65	+0·94	−1·09	−0·15	105 44 20·70	15·54	−5·16	+2·59	−2·57
32·45	F.B.	27	6 2 18·22	19·52	+1·30	−1·35	−0·05	71 41 20·87	21·15	+0·28	+0·10	+0·38
32·53	R.	Nov. 16	23 5 54·17	55·13	+0·96	−1·07	−0·11	95 1 10·82	5·33	−5·49	+5·09	−0·40
32·54	W.	17	23 55 0·69	1·72	+1·03	−1·09	−0·06	91 0 33·08	27·72	−5·36	+5·41	+0·05
32·54	F.B.	18	0 45 29·99	31·02	+1·03	−1·12	−0·09	86 49 37·41	34·12	−3·29	+5·52	+2·23
32·55	R.	20	2 33 28·68	29·63	+0·95	−1·24	−0·29	78 46 19·77	15·63	−4·14	+4·80	+0·66
32·65	W.	Dec. 15	0 22 38·43	39·25	+0·82	−1·08	−0·26	88 58 30·60	26·74	−3·86	+5·42	+1·56
32·68	W.	22	7 15 44·82	45·96	+1·14	−1·44	−0·30	72 8 43·60	45·79	+2·19	−1·82	+0·37
32·68	F.B.	23	8 20 54·11	55·47	+1·36	−1·40	−0·04	74 11 27·46	29·48	+2·02	−3·47	−1·45
32·70	R.	27	12 14 11·90	12·87	+0·97	−1·17	−0·20	90 12 6·04	8·74	+2·70	−5·89	−3·19
32·70	F.B.	29	13 59 0·42	1·63	+1·21	−1·14	+0·07	98 34 53·32	56·83	+3·51	−4·99	−1·48
Mean of Errors without regard to sign			...	...	s 1·023	...	s 0·236	...	...	″ 2·683	...	″ 1·139
Mean Errors for the Year			...	...	s +1·023	...	s −0·116					

Observers:—W., Mr. W. Wickham: R., Mr. W. H. Robinson; F.B., Mr. F. A. Bellamy.

TABLE II.

Radcliffe Observations of the Moon, 1885.

Errors of Longitude and Ecliptic Polar Distance. Corrected and Uncorrected for Error in Mean Time.

(Hansen − Observed.)

Day, 1885.	Errors of Longitude. Corrected.	Uncorrected.	Errors of E.N.P.D. Corrected.	Uncorrected.
Jan. 6	+ 1″·66	+ 18″·33	− 2″·97	− 4″·41
8	− 2·34	+ 13·55	− 0·80	− 2·10
Jan. 23	− 7·50	+ 10·15	+ 0·18	+ 1·63
Feb. 4	+ 1·38	+ 17·87	− 0·95	− 2·36
5	− 2·92	+ 13·08	− 1·34	− 2·54
Feb. 21	− 8·88	+ 9·25	− 0·38	+ 0·72
23	− 12·24	+ 6·51	− 1·57	− 1·23
24	− 12·80	+ 6·73	+ 2·26	+ 2·15
27	− 9·82	+ 8·97	+ 2·79	+ 1·52
Mar. 6	+ 2·64	+ 18·58	− 0·79	− 1·66
Mar. 23	− 14·71	+ 3·92	+ 1·69	+ 1·71
27	− 9·33	+ 8·93	+ 1·85	+ 0·43
28	− 7·98	+ 10·05	− 0·80	− 2·38
30	− 3·39	+ 13·95	+ 0·42	− 1·15
Apr. 3	+ 3·45	+ 19·40	+ 0·54	− 0·11
Apr. 22	− 4·94	+ 13·39	− 0·18	− 1·20
25	− 2·70	+ 14·79	+ 0·57	− 1·00
27	− 3·76	+ 13·27	+ 0·63	− 0·87
28	− 2·35	+ 14·37	− 0·48	− 1·76
29	+ 2·15	+ 18·55	− 0·43	− 1·45
May 1	− 1·04	+ 14·91	+ 2·18	+ 1·67
May 23	− 2·86	+ 14·29	− 0·19	− 1·70
27	+ 3·53	+ 19·71	− 1·44	− 2·27
28	+ 2·80	+ 18·82	+ 0·26	− 0·31
29	− 0·56	+ 15·30	+ 0·23	− 0·03
June 1	+ 1·38	+ 17·18	+ 3·36	+ 4·01
2	+ 5·68	+ 21·52	+ 2·45	+ 3·37

Day, 1885.	Errors of Longitude. Corrected.	Uncorrected.	Errors of R.N.P.D. Corrected.	Uncorrected.
	″	″	″	″
June 26	− 0·86	+ 14·99	−0·55	− 0·57
27	+ 2·85	+ 18·64	− 1·34	− 1·04
July 1	+ 2·47	+ 18·51	+ 2·67	+ 3·94
July 22	+ 0·35	+ 16·36	−0·72	− 1·05
23	+ 1·74	+ 17·64	+ 0·89	+ 0·86
24	− 4·12	+ 11 76	−0·47	−0·18
25	+ 2·36	+ 18·27	−0·26	+ 0·29
26	− 0·15	+ 15·72	+ 1·29	+ 2·13
Aug. 19	+ 2·62	+ 18·69	+ 0 62	+ 0·52
21	− 0·28	+ 15·57	+ 1·13	+ 1·64
22	+ 0·27	+ 16·20	+ 0·13	+ 0·91
24	+ 0·31	+ 16·56	−0·43	+ 0·82
25	+ 7·10	+ 23·52	+ 3·08	+ 4·48
Sept. 18	− 0·98	+ 14·98	− 0·23	+ 0·44
19	− 1 25	+ 14·85	+ 0·18	+ 1 17
21	− 4·11.	+ 12·34	−0·46	+ 0·92
25	− 0·34	+ 17 52	+ 0·45	+ 1·91
30	− 3·13	+ 15 92	+ 0·67	+ 0·36
Oct. 15	− 2·43	+ 13·57	+ 0·80	+ 1·40
16	− 1·57	+ 14·42	− 2·98	− 2·12
27	− 0·71	+ 18·57	+ 0·38	+ 0·20
Nov. 16	− 1·36	+ 15·36	− 1·00	+ 0·48
17	− 0·85	+ 16·31	−0·31	+ 1·23
18	− 2·12	+ 15·50	+ 1·53	+ 2·98
20	− 4·27	+ 14·60	−0·70	+ 0·43
Dec. 15	− 4·20	+ 12 84	−0·11	+ 1·33
22	− 4·21	+ 16·46	+ 0·92	+ 0·05
23	− 0·89	+ 19·60	− 1·28	− 2·52
27	− 4·02	+ 14·44	− 1·73	− 3·31
29	+ 0·46	+ 18·10	− 1·75	− 2 92
Mean of Errors without regard to sign	″ 3·459	″ 15 144	″ 1·066	″ 1·556
Mean Errors for Year	−″1·873	+ 15·″144	...	...

TABLE III.

Observations of the Moon, 1862 to 1885.

Mean Errors of Longitude. Uncorrected and Corrected for Error in Mean Time.

Year.		Errors of Longitude. (Hansen − Observed.) *Uncorrected.*	*Corrected.*	Year.		Errors of Longitude. (Hansen − Observed.) *Uncorrected.*	*Corrected.*
		″	″			″	″
1862	Greenwich	−2·829	−2·829	1874	Greenwich	+ 9·294	+0·561
1863	„	−1·606	−1·606	1875	„	+ 9·867	+0·365
1864	„	+0·121	−0·814*	1876	„	+ 9·800	−0·509
1865	„	+1·271	−0·220	1877	„	+ 9·234	−1·898
1866	„	+2·142	−0·217	1878	„	+ 8·219	−3 603
1867	„	+3·480	+0·357	1879	„	+ 9·631	−3·124
1868	„	+4·117	+0·280	1880	„	+10·265	−3·245
1869	„	+4·277	−0·352	1881	„	+10 622	−3·791
1870	„	+4·828	−0 657	1882	Radcliffe	+12·927	−2·508
1871	„	+6·955	+0·435	1883	„	+14·615	−1·547
1872	„	+7·309	+0·097	1884	„	+14·645	−1·907
1873	„	+8·239	+0·200	1885	„	+15·144	−1·873

Radcliffe Observatory, Oxford,
1886, *January* 6.

On Photographs of a new Nebula in the Pleiades, and of Saturn.

(*Letter to the President, from MM. Paul and Prosper Henry.*)

Nous avons reconnu à l'aide de la photographie, l'existence d'une nébuleuse nouvelle dans les *Pléiades*. Cette nébuleuse est voisine de l'étoile Maïa, qu'elle contourne, en partie, et d'où elle paraît s'échapper.

Elle affecte une forme spirale bien caractérisée et son étendue est de 2′ ou 3′ environ.

Il nous a été possible d'obtenir l'image de la nébuleuse sur 3 épreuves différentes : le 16 Novembre et les 8 et 9 Décembre derniers.

Nous ajouterons que, jusqu'à présent, nous n'avons pu l'apercevoir dans nos télescopes.

Nous avons l'honneur de vous adresser, Monsieur le Président, une reproduction agrandie, du négatif original, montrant la nébuleuse avec les étoiles environnantes.

Nous nous sommes permis d'y joindre quelques images de *Saturne* obtenues dernièrement.

Observatoire de Paris,
le 5 *Janvier*, 1886.

* Here change in the unit of time took place.

Photographic Maps of the Stars. By Isaac Roberts.

The letter from Admiral Mouchez, which was published in the *Monthly Notices* for November, shows the necessity for making known what has already been done in the direction he indicates.

In the year 1883 I made experiments on photographing stars with ordinary portrait lenses varying in aperture between three-eighths of an inch and five inches. The lenses were made by English, American, and French opticians. One of two inches aperture, by Lerebours et Secretan, gave the best results, and I adopted it as a standard for comparing the others. The comparisons were made by attaching two cameras to the declination axis of my 7-inch equatorially mounted Refractor, by Cooke, and taking simultaneous photographs of some well-known group of stars under precisely similar conditions.

The photographic plates were selected with regard to uniformity, and sometimes a plate would be cut in two, one-half being exposed in each camera under similar conditions.*

The result of these experiments and comparison with Mr. Common's great photograph of the nebula in *Orion* was that I gave Mr. Howard Grubb an order to make me a 20-inch silver-on-glass reflector with 100 inches focal length; the photographs to be taken directly in the focus of the mirror, to obviate any loss of light by a second reflection. The photographic telescope to be mounted on the same declination axis as the 7-inch Refractor, one being the counterpoise to the other.

Both telescopes move independently in Declination, but the motion in Right Ascension is common to both.†

The duplex telescope was mounted in March 1885, and after determining the size of the photo-field, the amount of overlap required, the time of exposure and preparing a method for easily registering the negatives, I was ready on May 1 to commence the regular work of taking photographs of the stars in the northern hemisphere, commencing at the Pole.

The size of the field which I adopted is 2° in Declination, and about $1\frac{1}{2}$° in Right Ascension, thus allowing sufficient margin for overlap. The time of exposure is fifteen minutes of clear sky, the photo-field being on or near the Meridian, and an allowance in time made for any mistiness or clouds which may arise when taking a photograph.

* On some recent experience in photographing stars with ordinary cameras and lenses by the author. *Proceedings* of the Liverpool Astronomical Society, vol. ii. p. 41.

† To Dr. Huggins is due the credit for devising this most ingenious, simple, and useful mode of mounting a reflector and refractor side by side; and the skill of Mr. Howard Grubb is well shown in the arrangements of the instrument to perform well the objects intended.

The frequent atmospheric changes that occur in our climate are important elements to be considered in fixing the time for exposing the photographs, and under this head the suggestion of Admiral Mouchez, for an exposure of one to three hours, if adopted, would make the progress of the work extremely slow.

Fifteen minutes of clear sky can often be utilised by keeping a good look-out, but an hour or three hours are rarely available.

Stars of small magnitude can be photographed by my reflector in fifteen minutes, but it would be misleading to name the photographic magnitudes by those which have been determined by eye-observations until comparisons have been made between large numbers of stars and the errors consequent upon the focussing of the instrument, the varying sensitiveness of the plates, the duration of the exposure, the varying actinism caused by moisture in the atmosphere, the varying density of image obtained in developing, &c., have been eliminated or reduced to a constant factor.

At present I will only refer to the experimental plates on which *Polaris* has been photographed when near the upper Meridian. Between September 15 and December 15, 1885, seventeen photographs have been taken with exposure of each plate between *one second* and *thirty-two minutes*. On some of them the *companion* is photographed faintly in *four seconds*, whilst on others it does not appear under an exposure of *one minute*, and on one plate it does not appear on exposure up to *sixteen minutes'* duration. I must defer the discussion of this subject to another occasion; but it is evident that the interpretation of photographs, as regards star colour and magnitude, should be done under due sense of the difficulties here named.

The diagram shows the form of record which I keep of the photographs.

The upper numerals in each space correspond with those marked on the film. The lower numerals are the Right Ascensions, and the degrees (84° to 90°) are the Declinations at the middle of each plate. A cross is marked upon each space after the photograph is taken and examined, and if more than one is taken of any space, a dot is inserted to record each additional photograph.

The Polar plate is a circle 2° in diameter; then concentrically with it are zones 2° in Declination, and of the widths respectively shown in Right Ascension, which, together with the convergence of the Meridians, give a large overlap for tracing stars on contiguous plates.

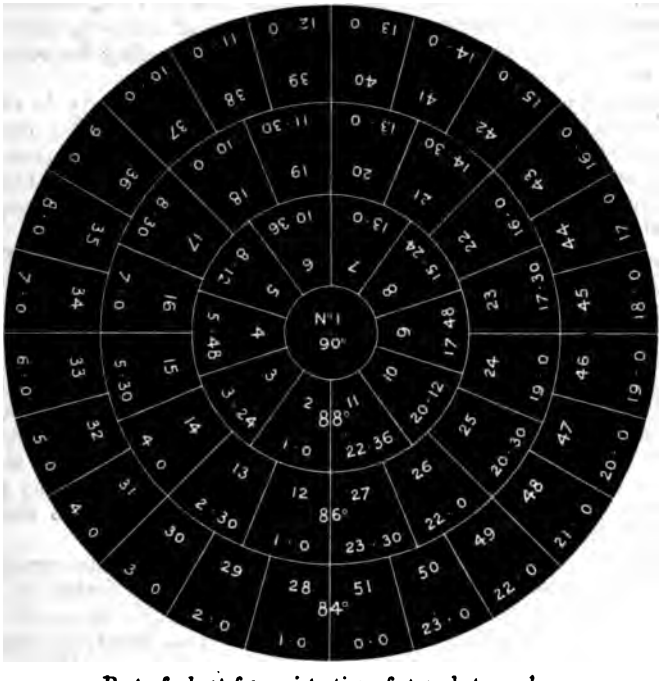
Each plate is marked on the film with the hour it was taken, the day, the month, the year, and the number, corresponding with that on the index chart. A book is also kept with these particulars in vertical columns, and remarks upon the state of the sky are recorded.

The following is a list of the photographs which have been taken up to December 29, 1885:—

Dec. 90° = polar circle.

Dec.	87	to	89	– R.A.	1	0	to	9	24	and	11	48	to 24 0
„	85	„	87	– „	1	0	„	24	0	= the zone complete.			
											h	m	h m
„	83	„	85	– „	1	30	„	8	30	and	15	30	to 24 0
„	81	„	83	– „	1	0	„	6	37	„	15	37	to 24 0
„	79	„	81	– „	1	0	„	7	18	„	17	0	to 24 0
„	77	„	79	– „	1	0	„	7	56	„	18	0	to 24 0
„	75	„	77	– „	1	0	„	7	15	„	20	15	to 24 0
„	73	„	75	– „	2	18	„	9	12	„	20	24	to 24 0
„	71	„	73	– „	2	50	„	6	50				
„	69	„	71	– „	4	24	„	5	21				

The negatives are stored in grooved wood boxes, each forming a sliding drawer, and containing 100 plates.



Part of chart for registration of star photographs.

The register number on the chart, in the book, and on the box refer to the number marked on the film of the negative.

How the negatives are to be reduced, and the information

which they contain is to be utilised astronomically, are questions which are constantly present with me, and the difficulties in answering them cannot be fully realised but by those who have seriously tried, and I may here enumerate some of them.

Most of the photographic plates have small specks in the film, many of which look like stars, and are difficult to distinguish from stars even when viewed through a microscope. Dr. Gill, at the Cape Observatory, meets the difficulty by taking two photographs successively of the same field, giving to each an exposure of one hour; but this makes the work almost Herculean, especially where clouds generally cover the sky. Another plan is to let the telescope run a few seconds of arc in Right Ascension during the exposure of the plate. This, again, is equivalent to two or more exposures of the stars upon different points of the film, and make what would be called one hour's exposure in reality only an exposure of some fraction of an hour. Admiral Mouchez suggests three exposures of an hour each, thus making a triangular figure with three positions of the same star. The objections to this are—great loss of time, confusion in positions of close stars, causing the discs of some to overlap others, and leaving the dirt specks still competing for recognition as stars.

Long exposures of the plates add to the difficulty in discriminating between specks and stars, by making the star discs appear large and black to the margins; but with a short exposure the small star discs show fainter, and often the atmospheric glare forms a halo round the star, which under the microscope materially assists in distinguishing between stars and specks.

All stars below, say, the 7th magnitude, require the aid of a lens or microscope to see them, but I do not find great difficulty in manipulating the light, the plate, and the microscope in such a way that the stars can with considerable certainty be distinguished from specks on the photographs taken with the 20-inch Reflector and exposure of fifteen minutes.

These statements refer only to viewing the stars by the aid of a microscope, and do not apply to printing them direct from the negatives, which in some form must be done before star photography can be appreciated and generally utilised as an astronomical pursuit. This is an additional problem, to those already referred to, that yet has to be solved.

The work of first importance is to secure good photographs of all stars down to the smallest magnitude practicable in as short a time as possible. They will in all future time be available for comparison with photographs which can at leisure be taken by large instruments for special researches.

The chart upon which I am engaged will be upon a scale twice the size of *Argelander's*, and, with an exposure of fifteen minutes for each plate, will contain a much larger number of stars than are shown on the *Atlas des Nördlichen Gestirnten Himmels*.

I submit a few negatives as samples of the general character of those already taken. Amongst them are plates of *Polaris*—*Andromeda* with the *Nova*—the *Pleiades* and *Nebula* in *Orion*.

On the Orbit of γ Coronæ Australis. By J. E. Gore.

The duplicity of this interesting binary star was discovered by Sir John Herschel at the Cape of Good Hope. Elements of the orbit were published by Captain Jacob in the year 1855 (*Monthly Notices*, R.A.S., vol. xv. p. 208), and he found a period of 100·80 years, with periastron passage, 1863·08. Some years since Prof. Schiaparelli published elements in No. 2,073 of the *Astronomische Nachrichten*, in which he assigns a period of 55·582 years, with an eccentricity of 0·6989, and periastron passage 1882·774. These elements were corrected by Mr. Downing (*Monthly Notices*, May 1883). As there are considerable differences between the elements found by Captain Jacob and Prof. Schiaparelli, particularly in the length of the period, I determined to make a new computation of the elements, and details of the results I have arrived at may be of interest.

The orbit was computed by a graphical method, in which the dimensions and position of the real ellipse are derived from those of the apparent ellipse by means of Thiele's harmonic ellipse. This latter ellipse being the orthogonal projection of the harmonic circle on a plane perpendicular to the line of sight, its major axis is of course equal in magnitude to the *latus rectum* of the real ellipse, and its angle of eccentricity is the angle of inclination of the plane of the real ellipse to the plane of projection on the background of the heavens. Thus the magnitude and position of the real orbit can be fully determined.

The following are the observations from which I have computed the elements. They have been corrected for precession, by the usual formula, to the epoch 1880·0:—

γ Coronæ Australis.

Angles and Distances: Angles reduced to 1880.

R.A. 1880, $18^h\ 59^m = 284° 45'$.

Dec. S. 37° 18′.

Correction $= 0°·0055 \sin \alpha \sec \delta = -0°·007$ per annum.

t	θ'	θ	r	Observer.
	°	°	″	
1834·47	37·1	36·78	2·66	Sir John Herschel.
1835·55	36·8	36·5	2·66	„ „
1836·43	34·5	34·2	2·66	„ „
1837·43	32·7	32·4	2·66	„ „
1858·203	343·42	343·27	1·53	Jacob.
1863·836	318·1	318·0	1·25	Powell.
1875·65	257·4	257·37	1·45	Schiaparelli.

t	θ'	θ	r	Observer.
1876·6	253°·1	253°·1	1″·67	O. Stone.
1878·49	242·6	242·6	1·36	,,
1879·69	240·0	240·0	0·87	Burnham.
1880·4	233·1	233·1	1·15	Russell.
1880·7	232·4	232·4	1·32	,,

A table of interpolated angles and epochs was then formed, and the apparent ellipse drawn by the method described in the *Handbook of Double Stars*, by Messrs. Crossley, Gledhill, and Wilson. The elements of the real ellipse were then derived from the apparent ellipse, as above described. The elements thus found are as follows:—

Elements of γ Coronæ Australis.

Position of node	$\Omega = 45°\ 25'$
Inclination	$\gamma = 47°\ 26'$
Position of periastron	$\lambda = 141°\ 0'$
Eccentricity	$e = 0·322$
Period in years	$P = 81·78$
Periastron passage A.D.	$T = 1886·53$
Semi axis major	$a = 1''·885$.
Mean annual motion	$\mu = -4°·402$

These elements are of course only provisional, and further observations during the next ten years will be required before an accurate computation of the orbit can be made.

The shape of the apparent orbit and the elements found above somewhat resemble those of 70 *Ophiuchi*.

A comparison was made between the positions computed from the graphical construction for the epochs of observation, and the observed measures, with the following results:—

Epoch	Position Angles. Observed.	Computed.	Difference. O−C.	Distances. Observed.	Computed.	Difference O−C.
1834·47	36°·8	37°·6	−0·80	2″·66	2′·33	+0″·33
1835·55	36·5	35·6	+0·90	2·66	2·33	+0·33
1836·43	34·2	33·8	+0·40	2·66	2·34	+0·32
1837·43	32·4	31·8	+0·60	2·66	2·34	+0·32
1858·20	343·27	342·65	+0·62	1·53	1·66	−0·13
1863·83	318·0	321·3	−3·30	1·25	1·47	−0·22
1875·65	257·4	259·0	−1·60	1·45	1·39	−0·06
1876·60	253·1	253·6	−0·50	1·67	1·39	−0·28
1878·49	242·6	243·7	−1·10	1·36	1·40	−0·04
1879·69	240·0	238·0	+2·0	0·87	1·39	−0·52
1880·40	233·1	234·4	−1·3	1·15	1·37	−0·22
1880·70	232·4	233·9	−1·5	1·32	1·37	−0·05

The computed angles have been corrected for the effect of precession.

It will be seen that there is a fair agreement in the angles but not in the distances. In one of Sir J. Herschel's measures at the Cape, and to which he assigns greater weight than the others, he gives the distance as 2″·40, agreeing fairly with the computed distance at that epoch.

It may be mentioned that as the major axis of the orbit is not far from the line of nodes, we see it nearly of its natural length, as in the case of the binary *η Coronæ Borealis*.

For the calculation of an ephemeris, the following formulæ are derived from the elements:—

$$(1)\quad u - 18°{\cdot}45 \sin u = -4°{\cdot}402\,(t - 1886{\cdot}53).$$

$$(2)\quad \tan \tfrac{1}{2}v = 1{\cdot}396 \tan \tfrac{1}{2}u.$$

$$(3)\quad \tan(\theta - 45°\ 25') = 0{\cdot}6764 \tan(v + 141°\ 0').$$

$$(4)\quad \rho = 1''{\cdot}885\,(1 - 0{\cdot}322 \cos u) \cdot \frac{\cos(v + 141°\ 0')}{\cos(\theta - 45°\ 25')}.$$

Where u is the eccentric anomaly, and v the true anomaly for the time t, θ the required position angle, and ρ the distance.

From these formulæ I have computed the following short ephemeris.

Date.	Position Angle.	Distance.	Date.	Position Angle.	Distance
	°	″		°	″
1886·0	200·7	1·20	1891·0	154·9	0·94
1886·53	196·7	1·13	1892·0	141·5	0·94
1887·0	193·0	1·08	1893·0	130·4	0·96
1888·0	184·3	1·04	1894·0	120·2	1·01
1889·0	174·7	0 99	1895·0	110·9	1·07
1890·0	164·9	0·96	1896·0	102·7	1·14

I may add that the above calculations were completed before I read Mr. Downing's paper. I find that the additional observations given by him all lie close to my interpolating curve, so that my results would not have been much altered had these additional observations been included.

On a new Variable Star of Short Period. By J. E. Gore.

I have lately discovered that the star 10 (Flamsteed) *Sagittæ* is an interesting variable of short period. I first suspected variation in this star in October 1879, when I found it fainter than 11 *Sagittæ*, although it was rated one-third magnitude brighter by Heis. I did not pay much further attention to the star until October 1885, when I again began to observe it, and a few consecutive fine nights in November showed that the star was certainly variable, with a period of 8–9 days. My observations have been fully confirmed by the Rev. T. E. Espin and Mr. E. F. Sawyer. The variation is approximately from 5·6 mag. to 6·4 mag. in the scale of the *Durchmusterung*, and the period about 8½ days.

The following are all my observations to end of December 1885.

The comparison stars are:—

	Mag.	
11 Sagittæ	5·8	In *Durchmusterung*.
9 Sagittæ	6·6	
DM. + 16°, 4086	7·0	

Observations of 10 *Sagittæ*.

	h	m	Mag.
1876 Dec. 14			5·6
1879 Oct. 7			6·3
1882 Nov. 2			6·0
1884 Sept. 21			6·4
1885 Oct. 15			6·0
31			5·7
Nov. 4	11	0	6·0
9			5·7
14	8	22	6·4
14	10	55	6·4
15	6	15	6·3
15	10	15	6·3
16	6	0	6·0
16	10	35	5·9
17	6	0	5·7
18	6	10	5·8
18	9	40	5·8
21	5	53	6·1

		h. m.	Mag.	Mag.
Nov.	28	8 0	5·9	5·6 Espin
	29	6 50	6·0	
	30	5 30	6·2	6·2 „
Dec.	1	5 50	6·4	6·4 „
	2	5 55	6·4	
	4	5 20	5·6	
	5	6 0	5·7	5·5 „
	7	5 50	5·9	6·1 „
	8	—	—	6·2 „
	9	7 30	6·35	6·4 „
	10	—	6·4	6·25 „
	11	—	—	6·0 „
	13	6 25	5·7	5·45 „
	14	—	—	5·6 „
	15	—	—	6·0 „
	16	5 50	6·0	
	16	7 25	6·1	
	16	8 25	6·1	
	17	—	—	6·4 „
	22	5 55	5·8	
	22	7 45	5·7	
	27	6 50	6·2	
	28	6 5	6·0	

Having plotted the observations in 1885 on square-ruled paper and drawn the light curve, I find the following dates of maxima and minima:—

Maxima.		Minima.	
1885	Oct. 31·3	1885	Nov. 14·3
	Nov. 9·3		23·1
	17·6		Dec. 1·9
	Dec. 3·8		10·0
	13·3		18·0
	22·3		

Treating the maxima by the method of least squares in the usual way, I find the following provisional elements:—

Period = 8·578 days

Mean epoch = 1885, Nov. 26·10

Variation 5·6 mag. to 6·4 mag.

Increase of light quicker than the decrease.

The minima treated in the same way give the following:—

Period = 8'43 days
Mean epoch = 1885, Dec. 1·46.

On the New Star in Orion. By J. E. Gore.

I first saw this star with a binocular field-glass on December 13, 1885, at 9.20 P.M., Dublin mean time. My attention was attracted to it by its very reddish colour, and its absence from Harding's charts.

When first seen the star was slightly but *distinctly* brighter than χ^2 (57) *Orionis*—about 0·15 magnitude. It has since slowly diminished in brightness, and the following are my estimates of its magnitude, the comparison stars being

	Mag.
χ^2 Orionis	6·3
Lalande 11088	6·6
DM. 20°, 1156	7·2

Observations of Nova Orionis.

		Mag.	
1885 Dec.	13	6·15	Clear sky.
	14	6·4	Drifting clouds.
	16	6·3	Strong moonlight.
	22	6·6	„ „
	25	6·9	„ „
	27	6·9	Clear sky; no moon.
	28	7·0	„ „
1886 Jan.	6	7·3	
	13	7·5	
	16	7·7	

Continuous observation was prevented by cloudy weather.

On a New Star in the Constellation of Orion. By Ralph Copeland, Ph.D.

On December 13, 1885, Mr. J. E. Gore, of Beltra, Ballysodare, Ireland, observing with a binocular, found a reddish star about 6 mag. some 20′ following χ' (54) *Orionis*. The star not being given by Harding, Lalande, Heis, or Birmingham, Mr. Gore suspected that it was either a "new star," or a remarkable variable. Mr. Gore's attention was attracted to it by its red colour and its absence from Harding's atlas.

On the receipt of these particulars from Mr. Gore on December 16, the star not occurring in the *Durchmusterung*, or, with certainty, in any of the usual catalogues, a telegram was immediately sent to Cambridge, U.S., and on the following day a circular giving a short account of the star was distributed by post. On the night of December 16 the star had been recognised by its orange-red colour, its place approximately laid down and the spectrum examined with a prism in front of the eyepiece as well as with a low-power spectroscope. Comparisons with neighbouring stars gave a magnitude of 6·3, from which it seems to be slowly declining, if reliance can be placed in the slight change in the following estimates:—

		Mag.			Mag.
Dec.	22	6·5	Dec.	26	6·5
	24	6·5		29	6·6
	25	6·5	Jan.	2	6·6

A prompt telegraphic response from Harvard College gave the brightness as 6·0 mag. on December 16.

At the first glance the spectrum was seen to be a specially beautiful one of type III., but it was not until a powerful compound prism was brought to bear on it on the 17th that its extraordinarily marked character was fully realised.

The large number of details thus rendered visible are shown in the following table, which gives the wave-lengths as they resulted from each set of observations, with the mean values.

Measures of the Spectrum of the New Star in Orion.

Description of line, band, &c.	Dec. 17.		Dec. 18.		Dec. 26.		Means. m.m.m.
Spectrum begins	669 ±				671 ±		670 ±
Dusky band begins	626·9				627·1		627·0
„ „ ends	616·4				613·5		615·0
Maximum of great bright band					611·0		611·0
Dusky band begins	597·2	593·7					595·5
„ „ ends	587·0	585·4				583·9	585·4
Almost a bright line					584·1		584·1
Maximum in bright band	577·1						577·1
Brighter from					559·2		559·2
To the beginning of a dimmer part at					549·0		549·0
Sharp edge towards the red of a bright band; brightest part of the spectrum	544·1	542·7	542·6		541·7		542·8
The band fades away at					520·4		520·4
Dark line: darkest part of spectrum...			518·9	517·0	519·0	to 516·8	517·9
Very bright line: beginning of band	517·4	515·3	515·6		516·2	516·3	516·2
Second bright line	515·7	513·1 512·4					513·7
The band fades away, ending at	500·4		504·4		503·2		502·7
Dark line			495·5				495·5

Description of line, band, &c.	Dec. 17.	Dec. 18.	Dec. 26.	Means m.m.m.
Bright line: beginning of band	494·4	493·9	494·8	494·4
Second bright line	492·3			492·3
The band fades to invisibility at	484·5		485·9	485·2
Bright line; fairly visible Isolated bright line, just discernible	... ...	478·0	477·6	477·8
Bright line; fairly visible	472·3		472·2	472·2
Fades off to			466·2	466·2
Faint luminous band			456·2	456·2
End of spectrum	450 ±			450 ±

The sketch gives an idea of the relative degree of brightness of the various parts of the spectrum.

The spectrum is unmistakeably of the third type, of which *a Orionis* is the brightest member. But in this star the *bright bands* are so strikingly developed that they form the most salient parts of the spectrum. Adopting this view, an examination of the preceding numbers and the descriptions of the bands, &c., to which they refer, reveals the startling fact that this spectrum is not so much a continuous one, interrupted by dark lines and dusky bands, as *a not very luminous spectrum upon which a series of bright bands are superposed*. One of the bright bands, that beginning with the "very bright line," w.-l. 516·2 m.m.m., is most readily identifiable as the great hydro-carbon band seen in the spectrum of every comet that has been examined under favourable circumstances. This identification is strongly supported by the second bright line 513·7, which is also found both in hydro-carbon and cometary spectra. It is, however, on bringing the spectra of the star and of the blue flame of a spirit-lamp at the same time into the field of the spectroscope that their exact agreement becomes most evident. For not only do they agree perfectly in wave-length and in beginning with two plainly distinguishable bright lines, but also in the delicate gradations of light by which they similarly fade away towards the violet, thus forcing the extreme probability of a common origin upon the observer.

But the presence of luminous lines does not rest on this single band, for the second cometary and hydro-carbon band, which has its bright edge at w.-l. 472·9 (Hasselberg, *Ueber die Spectra der Cometen*), is also found in the new star's spectrum at w.-l. 472·2.

Of the three other luminous bands agreeing with the coal-gas spectrum, which were all measured at Dun Echt in that of Comet 1881, III.,* two lie beyond the limit to which I have yet traced the spectrum of this star, and the third, falling between w.-l. 563 and 534 in a bright and otherwise difficult part of the spectrum, has not yet made its possible presence evident.

This leaves the origin of the bright bands beginning at 542·8 and 494·4 an open question; but, excepting their general appearance, there is no reason why they should be due to the same substance as the great band at 516·2. On the other hand, the presence of the bright hydro-carbon bands in a spectrum of type III. removes any difficulty there may be in accepting Secchi's conclusion that they appear in a reversed (dark) form in spectra of type IV.

The position of the new star was determined by Dr. L. Becker with the Dun Echt transit circle of 8·6 ins. aperture, as below, the places being based on the catalogue of the *Berliner Jahrbuch*.

* *Copernicus*, vol. ii. p. 227.

1885.	Mean R.A.	Mean Decl.
	h m s	° ′ ″
Dec. 17	5 48 59·52	+20 9 13·7
18	59·49	14·2
22	59·49	14·5
24	59·56	15·9
26	59·55	13·9
Mean place 1885·0:	5 48 59·52	+20 9 14·4

On January 2, 1886, the Rev. S. J. Johnson wrote to me there was a star in Bode's Maps (1782) near the *Nova*, but which is not in the larger or smaller maps of the S.D.U.K. or any other atlas in his possession. In the description of the *Uranographie* Bode refers the star to Hevel, who gives it in the *Prodromus Astronomiæ*, on pp. 228 and 296, as "in Clavâ intermedia." It is duly entered in map Qq of the *Firmamentum Sobiescianum*,* and forms No. 1064 of Baily's edition of Hevel's Catalogue in vol. xiii. of the Society's *Memoirs*. Respecting it, Baily says: "I cannot find any star that will accord with this position; neither can I discover any observations of it in the *Machina Cœlestis*. It is not in the Index to that work. The two other neighbouring stars, which are designated by Hevelius as 'In clavâ præcedens' and 'sequens,' were observed on April 18, 1667."

Dr. L. Becker, on reducing all three stars from 1660 to the date of the *Durchmusterung*, finds:

		1855·0. Hevel.	Durchmusterung.	H−D.M.
		h m s	h m s	s
In Clavâ præcedens	α	5 45 54	5 45 48	+6
		° ′	° ′	′
	δ	+20 15·2	+20 14·8	+0·4
		h m s		
In Clavâ intermedia	α	5 51 30		
		° ′		
	δ	+20 15·1		
		h m s	h m s	s
In Clavâ sequens	α	5 55 29	5 55 19	+10
		° ′	° ′	′
	δ	+20 7·5	+20 8·4	−0·9

The Meridian observations of the new star give:—

			Hevel − Nova
		h m s	m s
Nova Orionis, 1855	α	5 47 13	+4 17
		° ′	′
	δ	+20 8·7	+ 6·4

* The Dun Echt copy of this atlas bears the autograph "J. E. Bode. 1774, 10/24, Berlin."

If Hevel did really observe the same star as Mr. Gore there must be an error of 1° in Hevel's observation. Hevel calls the star 7 mag., but there is no star of that size either in the Bonn maps or in the heavens with which it can be identified, without the assumption of some error.

Flamsteed measured the places of the quadrilateral of stars formed by 54, 57, 61, and 62 *Orionis* with the sextant on February 20, 1680, but makes no mention of any star inside the group.* The star does not occur in Sufi or any of the ancient catalogues.

Dun Echt Observatory:
1886, *January* 7.

Observations of the Spectrum of Nova Orionis made at the Royal Observatory, Greenwich. By E. W. Maunder.

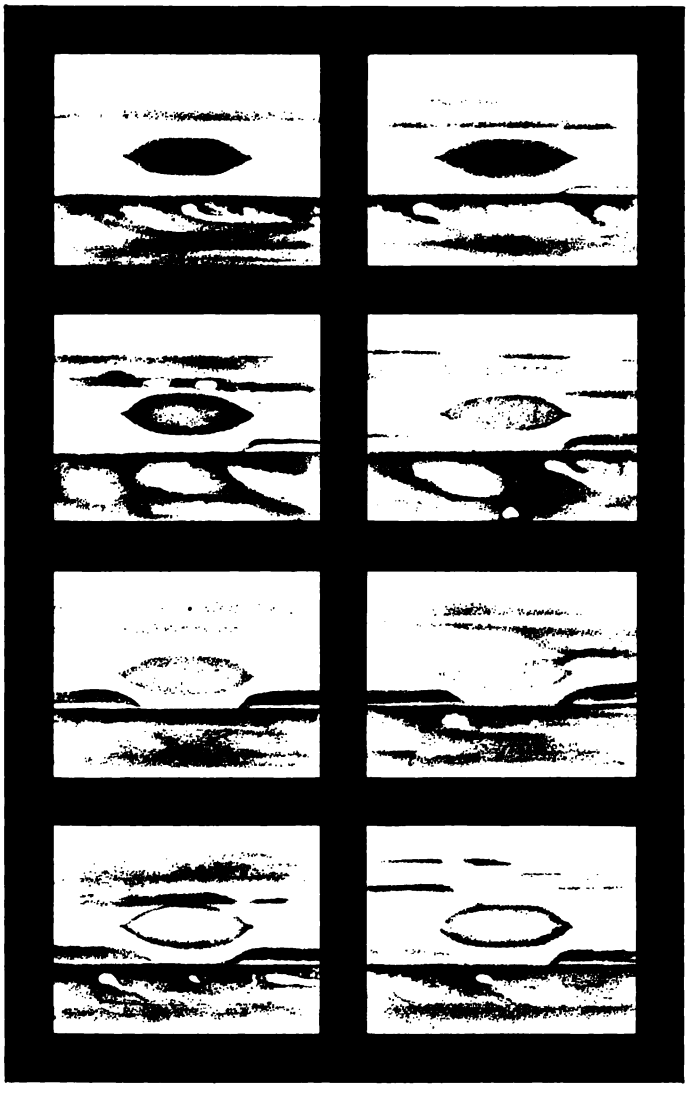
The spectrum of the new variable, discovered by Mr. Gore near χ' *Orionis*, was examined on the evening of 1885, December 29, with the "half-prism" spectroscope reversed, and a train of one "half-prism," giving a dispersion of about 5° from A to H. A magnifying power of 28 was used upon the viewing telescope. A cylindrical lens was employed before the slit, which was not quite sufficiently narrow to separate the bright lines of the magnesium spectrum which correspond to b_2 and b_4, Slit width=0·00688 in. corresponding to about 7″ of arc.

The spectrum is an exceedingly pronounced example of Secchi's third type. The dark bands are *very* dark; the bright zones or interspaces *very* bright, and with a low dispersion would undoubtedly present the appearance of bright lines. With the dispersion employed, however, no bright lines could be detected, nor was any local irregularity of brightness, which could reasonably be suspected to be a bright line, seen anywhere; notwithstanding that, as just stated, the brilliance of the bright zones, especially close to the sharp edges of the dark bands, was very striking.

Four dark bands were very conspicuous. Adopting the numeration employed in the observations of β *Pegasi*, made on 1876, October 18, and published in the volume of Greenwich Observations for 1876, these were Bands IV., V., VI., and VII. The following three measures were obtained of the sharp, more refrangible edge of Band VI. (Band 7 in Dunér's nomenclature):—

	Wave-length. Tenth-metres.
	5167·76
	5170·29
	5170·57
Mean ...	5169·54

* *Hist. Cal.*, i. p. 81.



Jupiter's Red Spot and the region near.

	h	m		h	m
1. 1880 Nov. 19.	9	23.	2. 1881. Sep. 28.	13	11.
3. 1881 Dec. 7.	10	40	4. 1882 Oct. 30.	16	10
5. 1883 Oct. 15.	15	37	6. 1884 Feb. 6.	9	29
7. 1885 Feb. 25.	12	50.	8. 1885. May 9.	8	8.

10 inch reflector. powers 212 and 252.

W.F.Denning del
W. H. Wesley lith.

West Newman & Cº imp

Bands IV. and V. were identified beyond any doubt by their proximity to the line λ 5527, of the magnesium spectrum and Band VII. (Dunér's Band 8), by its neighbourhood to the double line of air λ 5003, and it was clear that they occupied their usual places. These were measured in the spectrum of *β Pegasi*, on the occasion above referred to, as λ 5610, λ 5450, and λ 4953. The dark line on Band VI., the wave-length of which was measured in the spectrum of *β Pegasi* as λ 5272 (Dunér's Band 6), was not identified, but Band VI. was so broad that it probably embraced this line or sub-band within its limits. A band was also seen at D, without doubt Band II., λ 5869 (Dunér's Band 3), and another beyond F, probably Band VIII., λ 4761 (Dunér's Band 9). Band I., λ 6169 (Dunér's Band 2), was only just suspected. The spectrum was not traced far enough for bands to be detected beyond these, either towards the red or the violet. Some feeble bands or lines were suspected between Bands V. and VI., but none of the great bands were resolved into lines. The *breadth* of the great bands seemed to be about the same as usually observed in stars of this type. The dark line or narrow band at λ 5272 is often confused with Band VI., and the breadth of the latter was not greater than would result from this cause.

Royal Observatory, Greenwich:
1886, January 6.

Changes in the Red Spot on Jupiter. By W. F. Denning.

It may be interesting to record and compare some of the visible changes which have occurred in the aspect of this remarkable formation; and with this end in view I send the accompanying drawing of the appearances observed in my 10-inch Reflector on several occasions since 1880.

A brief *seriatim* description of the most noteworthy features and variations of the spot and region near will be sufficient for the present purpose. A discussion of the phenomena in their physical relations would only be premature pending the further accumulation of records. In each case the spot was delineated at mid transit.

1. 1880, Nov. 19, $9^h\ 23^m$.—Red spot very dark and definite in outline with minute black speck at following end. N. of the centre the white equatorial spot is seen, the two markings being in conjunction.

2. 1881, Sept. 28, $13^h\ 11^m$.—The spot very red and conspicuous, with small black marks at E. and W. extremities. Immediately N., and slightly preceding, the white equatorial spot is observed with its normal light-trail running to N.E. and confused with other irregularities on the equator. N. of the following end a very curious narrow, curved belt, of red colour,

is traced emerging from the great S. belt and running parallel with it far to E. This feature was also visible in 1880, Sept., though it afterwards faded, and a detail of very similar character and position is figured by Mr. Gledhill near his ellipse of 1869–70.

3. 1881, Dec. 7, $10^h\ 40^m$.—Red spot evidently fading in the central part, though the elliptical outline remains equally bold, especially on the N. side, where it abuts great S. belt. The black specks at the longitudinal limits of the spot are still very obvious, and the bent belt N. of the following end now appears much plainer than before. Several large irregular white patches lie near equator, and there is a singular alternation of oval white and dark markings on a belt closely outlying the spot on its S. side.

4. 1882, Oct. 30, $16^h\ 10^m$.—The spot very much fainter generally, though still a fairly prominent object on the planet's surface. The decadence has chiefly affected the central region; the dark ends are still apparent, and the integrity of form is not disturbed. The bent belt N. following has further developed: it is broader, and the red colour more conspicuous. It has now extended itself so much as to completely environ the planet, and where it comes up to the N. preceding end of the red spot, it suddenly dips N., and merges into the great S. belt, so that the appearances near the spot's following end are here repeated, and the effect is a symmetrical jointure of the two belts relatively to the red spot. The white equatorial spot is shown N. of the following side, but the variegated belt just S., seen in Dec. 1881, is gone.

5. 1883, Oct. 15, $15^h\ 37^m$.—Red spot very faint and apparently of nearly uniform tone. The bent belt has now become a very prominent feature, and forms a basin in which the red spot rests, though perfectly detached. Indeed, the region separating them is very bright, as if the lucid zone in the same latitude as the red spot ran N. to avoid contact. The shoulders of the bent belt are very dark, but there is rather an absence of other detail.

6. 1884, Feb. 6, $9^h\ 29^m$.—Spot very faint, though under good definition it is well seen. A striking feature now arrests the eye in the form of a narrow dark belt which is actually connected with the spot on S. following side. Though the N. belt has avoided the spot so persistently, here is a belt curving down right into the spot! The fact is very interesting, and goes far to prove that the bright belt, in curving down to avoid commingling with the red spot, carries the faint S. belt with it, and thus reproduces a parallel formation to the bent belt on the spot's N. following side. This junction of the belt and spot was observed in Jan. and Feb. 1884, by several other observers independently. The sketch shows a white equatorial spot (though not the one so frequently observed), and the narrow bright line which is now all that divides the new and old S. belts.

7. 1885, Feb. 25, $12^h\ 50^m$.—The red spot is but a mere skeleton of its former self. It exists only in outline, and reminds

one forcibly of Gledhill's ellipse. There is a dusky belt, not smooth in tone, immediately S., and several white spots are seen in the usual position on the inner margin of the great S. belt. The bent belt on the N. following side of the spot is still very dark, but the opposite side has faded greatly. All the interior region of the red spot seems involved in a white cloud, which has, however, quite failed to break its continuity of outline. Contemporary with the virtual obliteration of the spot's central area, the line of the ellipse appears much plainer, as if gaining in prominence. The following end is darkest.

8. 1885, May 9, $8^h\ 8^m$.—Red spot has become very much plainer, and the interior light cloud appears nearly dissipated. The following end of the spot is very dark, and shows the black spot noticed in previous years. There is a narrow dark belt distinctly bent down from the spot's S.W. side, and actually connected with it. Some distance further S. there is a very dark broken belt. A white spot is figured N. of the preceding side of the red spot, and the marked decadence of the bent belt on its N. preceding margin, noticed in Feb. 1885, has become more decided. It is now very narrow and faint; it seemingly exists in duplicate on the S. preceding region of the spot. Definition very superb when these details were observed.

As to the present aspect of the red spot, it does not differ essentially from that portrayed in fig. 4 for 1882, Oct. 30. Relatively to its appearance in 1879, '80, and '81, it is faint and shorn of its striking character. But it is much more distinct than in 1883 or 1884; the enclosed light cloud is gone, and the red ellipse of the preceding winter (1884–5) has become diffused into an oval marking similar to that which the spot assumed more than three years ago. I have obtained the following observations during the present apparition:—

Date.	Spot central.	Date.	Spot central.
	h m		h m
1885 Oct. 24	17 32	1885 Dec. 28	16 21
26	19 10	1886 Jan. 2	15 29
Dec. 1	19 0	4	17 6
9	15 40		

These times prove that the rotation period of $9^h\ 55^m\ 38^s{\cdot}99$ (=870°·31 Daily rate) adopted by Mr. Marth in his Ephemerides (*Monthly Notices*, vol. xlv. No. 9) corresponds very closely indeed with the present motion and position of the spot. His predicted times based on this rate show an average difference of less than two minutes with the observed times as above. According to my observations here, the spot has exhibited an equable motion since the summer of 1882 (after becoming so much fainter), the mean period being $9^h\ 55^m\ 39^s{\cdot}1$. My comparative rotation periods were:—

Dates of Limiting Observations.	No. of Rotations.	Period. h m s
1882 July 29–1883 May 4	674	9 55 39·1
1883 Aug. 23–1884 June 12	710	9 55 39·1
1884 Sept. 21–1885 July 8	700	9 55 39·2

As far as the observations have already progressed during the present opposition, I find the period $9^h\ 55^m\ 40^s{\cdot}3$ from 174 rotations, but the interval of 72 days is too short for good results.

As to the new red spot, so frequently observed during the last opposition and following the old spot $1^h\ 48^m$ ($=65°{\cdot}3$) in the same latitude, I looked for it most carefully before sunrise on January 5, but failed to recover it. It has either disappeared altogether or become extremely faint, like the belt on which it is projected.

Note on the Biela Meteors. By Richard A. Proctor.

At the last meeting of the Society a remark was made to the effect that the radiation of the Biela meteors from an area, instead of a point, might be regarded as affording evidence in favour of a theory propounded by an anonymous writer in the *Times*, who, in an essay on comets and meteors, had maintained that the Biela meteors were probably ejected from the earth. As the author of the article in question, I desire to point out that it has never occurred to me to regard the meteors following Biela's comet as earth-born bodies. I have never heard of anyone who has suggested that they may have been so; nor can I imagine that any astronomer of repute would fail to recognise the overwhelming objections against such a theory. The article referred to definitely mentioned the Biela meteors as probably sprung from Jupiter.

The wide area of the radiant region, by the way, is no new phenomenon. It is interesting as showing how untenable is the belief that a radiant region of small area—not more than two degrees in diameter, for example—can safely be assigned to meteors having the so-called stationary radiants. So soon as the radiant regions of these systems come to be dealt with by several observers, it will be found that they are much larger than has been supposed. All occasion for the assumption of very great velocities will then disappear; nor need the laws of geometry be rejected for the sake of stationary radiant regions, as distinguished from radiant points.

The wide area appears to me to be unquestionably due to changes of direction caused by atmospheric resistance. If this affects meteors falling at the same time in originally parallel streams on the same region of our air, much more must it affect meteors falling in different months.

Barrow-in-Furness:
1886, January 6.

Observations of the Meteors of 1885, *November* 27, *made at the Radcliffe Observatory, Oxford.* By W. H. Robinson.

(*Communicated by E. J. Stone, M.A., F.R.S.*)

At $6^h\ 0^m$ P.M. (G.M.T.) great numbers of meteors were observed to be falling, and from comparison with subsequent observations in evening it was inferred that they were thicker about 6.30 than later. But clouds prevailed, more or less, in parts of the sky nearly all the evening.

About $7^h\ 0^m$ the sky was fairly clear, but at

$8^h\ 45^m$ thickly overcast.

At $6^h\ 30^m$, facing South: the meteors appeared to be falling in parallel lines, like the tracks of rain drops. Estimated that they were cutting parallels of Declination at about angles of 45°; but in order to secure greater accuracy reference was made to the stars, and here it was found that the direction was invariably from *α Andromedæ* to *α Pegasi*. Facing North: the meteors were all showering in one direction, as noticed in S., and here it was estimated that the general path formed with the meridian (*sub polo*) an angle of 30°, or more accurately, as ascertained at

$7^h\ 23^m$, from *Polaris* through a point half way between *ε* and *ζ Ursæ Majoris*. They were seldom 1^s in duration, generally $0^s{\cdot}5$ or less, and the usual length of path was between 5° and 10°. The meteors were fairly uniform in brightness, and equal to the brightest stars in *Ursa Major*, or about the second magnitude. Some were equal to *α Lyræ*, and many fainter than third magnitude. Did not notice any as bright as *Venus*, although specially watching for them.

$6^h\ 42^m$. Nearly overcast.

$6^h\ 45^m$. Breaks in N.E. Meteors still falling fast, and often visible through cloud when no stars appeared.

$7^h\ 0^m$. Sky clearing. In the W.S.W. the meteors were falling in the direction *α* to *δ Aquilæ*.

$7^h\ 33^m$. Facing East: appeared to be falling in the Prime Vertical.

$7^h\ 45^m$. Facing West: here also running down the Prime Vertical; clouding.

$8^h\ 15^m$. A clear patch in E. Meteors evidently becoming fewer here.

$8^h\ 30^m$. Clear in places. From south side of Observatory: noticed they were still falling rather fast, average

30 per minute. The brightest leave phosphorescent trains visible for more than 1ˢ after the meteor had disappeared.

8ʰ 38ᵐ. Several bright meteors in South about the magnitude of *Capella* and cutting near square of *Pegasus*. Observed in break of clouds.

9ʰ 30ᵐ. Partly clear in South. Meteors still falling fairly fast.

The tracks given above when referred to the stars are accurate, but the remainder are only approximate. From the former it is inferred that the radiant-point is situated about

R.A. 1ʰ 30ᵐ and N.P.D. 48°,

or very near 50 *Andromedæ*.

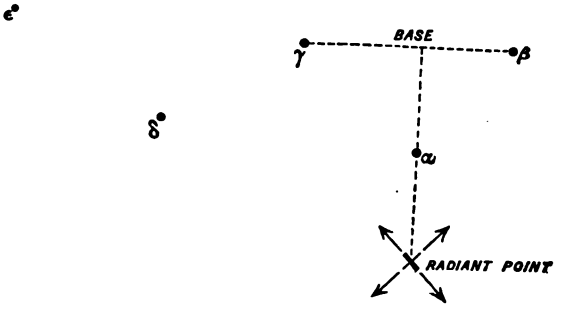
Radcliffe Observatory, Oxford:
1885, *December* 15.

Display of Meteors, 1885, *November* 27. By W. Wickham.

(*Communicated by E. J. Stone, M.A., F.R.S.*)

On the evening of Friday, November 27, I was walking between Islip and Charlton, two villages six to nine miles N.N.E. of Oxford. The night was very dark and cloudy, but at 5.35 P.M. (nearly) I noticed repeated bursts of light behind the clouds.

The sky began to clear in patches, and once, about 6.15 P.M., was almost free from cloud. Having no light with me I could neither record time nor track beyond making the following mental notes:—I remarked that the thickest display occurred about *Cassiopeia*, and it soon became evident that the radiant-point was somewhere S. beyond the five bright stars of *Cassiopeiæ*. Further examination led me to fix the radiant-point at a distance south beyond *α Cassiopeiæ*, equal to a perpendicular let fall from *α Cassiopeiæ* upon a base drawn between *β* and *γ Cassiopeiæ* (and near *ν Cassiopeiæ*), as shown in the following sketch:—



Most of the time I was facing N.N.E., but turning due south I noticed the general direction of the meteor-paths to be in a

line drawn between *α Andromedæ* and *α Pegasi*. During the clear interval, about 6.15 P.M., I saw thousands of meteors, and counted six falling simultaneously through the N.N.W. The meteors seemed generally of the same magnitude (about 1st star mag.), but I noticed many smaller when the sky was clear for a few minutes. At 6.15 P.M. (about) there were two bright meteors, about the size of *Jupiter*, one on the N.W., the other on the S.W. horizon, both of which exhibited a decided green colour.

All the paths and durations seemed unusually short, the former comprising a luminous track and then a bright burst. With the exception of one hour (from 6.30 to 7.30), I kept watch till 11 P.M., but clouds generally prevailed, although I could see frequent bursts behind them.

Radcliffe Observatory, Oxford:
1885, *December* 15.

The Meteor Shower of 1885, *November* 27.. By Major A. C. Bigg Wither.

A grand display of meteors was seen at Quetta, Beluchistan (67° 5′ E., 30° 12′ N.), on November 27, 1885. At 10 P.M., local time, the shower was incessant, and I estimated that over the whole visible hemisphere six or eight meteors in every second were falling at this time. The radiant-point was about half way between the three principal stars in *Aries* and *Cassiopeia*, in *Andromeda*, close to the well-known nebula; and as this part of the heavens was nearly in the zenith at this time, the meteor shower had, so to speak, a most symmetrical appearance. The meteors were mostly not very brilliant—on an average like stars of the 3rd magnitude, moving over arcs of 8° or 10°; but there were some brighter even than stars of the 1st magnitude. Unfortunately circumstances did not permit me to observe for more than a few minutes, and it was only by accident that I saw the shower at all.

Quetta, 1885, *November* 29.

The Meteor Shower of 1885, *November* 27. By Major G. Strahan.

I have been fortunate enough to witness here, on the night of the 27th inst., a most superb display of meteors, and as it is possible they were not visible in England, a short account of them may be of interest to the Society. I first noticed them on leaving my house at about 7.20 P.M., local time, and at that time the shower was most fully established (longitude of Agra is about 5^h 10^m E.). It was impossible to count them; there were often six or seven visible at once, and there were rarely

intervals of four seconds without one being seen. I should estimate the frequency to be fully fifty per minute or more. The time of maximum must have been about 9.30 P.M., but the full force of the shower really varied very little between the hours of 7.30 and 11.30. A few were still visible at 2 A.M. About 50 per cent. of them might have been equal to 3rd magnitude stars. Meteors equal to 1st magnitude stars were comparatively rare—perhaps not one a minute. A few of the brightest left streaks, slightly reddish, which remained visible some four or five seconds. Some almost stationary meteors were seen near the radiant-point, which I estimated at

R.A. $1^h\ 45^m$. Decl. $+46°$.

I have not had much experience in tracing the paths of meteors, and found it difficult to determine an exact radiant-point; it appeared to me that the tracks of these bodies would not exactly intersect anywhere; but the position given above is the nearest I could arrive at. It is nearly midway between the stars γ *Andromedæ* and 51 *Andromedæ*. I trust that more complete accounts of this phenomenon may reach you from other observers here.

Agra, 1885, *November* 29.

The Meteor Shower of 1885. By Capt. D. Wilson-Barker.

(*Communicated by the Secretaries.*)

On November 27, in lat. 25° 5′ N., long. 60° E. (59° to 61°) we observed a magnificent display of meteors. As soon as the Sun set we could see a regular shower, which reached its maximum between 9.30 P.M. and 10. At that time the third officer and myself, counting in turns, by taking a certain portion of the sky, computed that they were shooting at least 600 per minute. Sir H. Mance, C.S.I., who was on board, thought 1,000 per minute. With a few exceptions they were small meteors. In one exceptional case the track was visible for eight minutes, and for some time longer with the aid of a glass. The radiant-point was situated about the constellation *Triangulum*, a few being observed to shoot from other directions. Towards 3 A.M. the number became plainly less, partly caused perhaps by the Moon. The next evening we saw very few.

S.S. "*Dacia*," *Suez*:
1885, *December* 22.

Observations of the Comet 1885 (*Brooks*), *at Harrow, with the* 18½*-inch Equatorial Reflector.*

By G. L. Tupman.

1886	G.M.T.	♂−✶ Δα	♂−✶ Δδ	Comp.	♂ α	L/p	♂ δ	L/p	
	h m s	m s	′ ″		h m s		° ′ ″		
Sept. 6	9 54 15·2	−1 52·6	−8 35	14	14 3 47·4	+8·719	+38 24 15	+9·847	1
9	9 29 21·1	−0 43·44	−0 12·4	12	14 21 28·46	+8·730	+39 38 43·0	+9·808	2
11	9 28 15·1	+0 21·56	−8 4·5	16	14 33 54·81	+8·736	+40 23 12·6	+9·795	3
13	9 42 43·4	+1 14·27	+3 28·3	13	14 46 53·62	+8·738	+41 3 28·3	+9·806	4
13	9 42 43·4	−0 9·98	−7 7·1	13	14 46 53·62	+8·738	+41 3 26·6	+9·806	5

Mean Places of the Comparison Stars for 1885·0.

	α h m s	s	δ ° ′ ″	″	
1	14 5 39·78	+0·22	+38 32 32·4	+ 8·0	WB_2, 14^h, 77, 78
2	14 22 11·73	+0·17	+39 38 46·2	+ 9·2	,, 451
3	14 33 33·03	+0·22	+40 31 9·5	+ 7·6	,, 681, 2
4	14 45 39·20	+0·15	+40 59 48·9	+11·1	,, 960
5	14 47 3·45	+0·15	+41 10 22·4	+11·3	,, 973

Sept. 6. Ring Micrometer. Power 60. Comet has no nucleus: not possible to observe its place with accuracy.

Sept. 9. Ring Micrometer. Comet a little brighter than on Sept. 6.

Sept. 11. Ring Micrometer. Some haze. Observations difficult. The outer and inner rings differ $1^s{\cdot}5$ and $3''$.

Sept. 13. Crossed Bar Reticule. Power 120. Clear night. Comet 3′ diameter; no nucleus. The R.A.'s of the stars were used to determine the orientation of the reticule.

The comparisons are corrected for refraction and comet's motion.

Biela's Comet.

(*Extract from a letter to Mr. Knobel from Dr. Gill, dated Dec.* 5, 1885.)

"I have been sitting up every night to look for Biela's Comet, near *ζ Centauri* (visible only from 2 to 3.30 A.M.) We have often had fine nights since the 28th till 1 A.M., when the sky has clouded, and I have not yet seen *ζ Centauri*, much less the comet, since the 28th.

"P.S.—Since writing I have searched near *ζ Centauri* and all around in vain for Biela."

Occultation of Aldebaran, 1886, January 16. By Prof. Robert S. Ball, LL.D., F.R.S.

In an interval between two falls of snow, the occultation of *Aldebaran* was observed at this place under favourable circumstances.

I observed with the "South" Equatorial of 12 inches aperture, Mr. Rambaut used the 5-inch Equatorial, while we also had the benefit of the assistance of Mr. J. H. Longford with an excellent 3-inch "Student's Equatorial," by Grubb.

Mr. Longford's time was recorded on the chronograph of the Observatory. Mr. Rambaut took the time from a controlled mean time clock with eye and ear, while I used a chronometer showing sidereal time.

The immersion appeared quite instantaneous in all three instruments.

The definition was very good at the time of both phases.

The times were

	Immersion.	Emersion.
	h m s	h m s
Dr. Ball	7 20 44·4	8 10 31·6
Mr. Rambaut	7 20 43·0	8 10 30 9
Mr. Longford	7 20 44 9	

Dunsink Mean Time.

The Observatory, Dunsink, Co. Dublin:
1886, *Jan.* 17.

Observations of Comets d, 1885 (Fabry), and e, 1885 (Barnard) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of Declination.

Comet d, 1885.

Greenwich Mean Solar Time. 1885.	Observer.	✱−★ R.A.	Corr. for Par. & Refract. in R.A.	✱−★ N.P.D.	Corr. for Par. & Refract. in N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star
d h m s		m s	s	′ ″	″		h m s	° ′ ″	
Dec. 24 7 49 24	H.	+0 25·84	+0·14	− 1 35·4	−3·1	4	23 54 19·26	69 18 56·2	*a*
27 9 27 14	A.D.	−0 4·78	+0·22	−10 42·6	−3·9	3	23 50 3·68	69 17 21·6	*b*
9 36 34		−0 4·94	+0·22	− 0 15·1	−3·5	3	23 50 10·59	69 16 49·0	*c*
9 47 43		−1 3·94	+0·23	−12 44·7	−4·2	3	23 50 0·64	69 17 6·7	*d*

Comet e, 1885.

Dec. 15 11 41 17	H.T.	+0 47·70	+0·08	− 3 28·5	−3·7	5	3 52 29·49	84 5 37·0	*e*
11 44 19		+0 3·46	+0·08	− 5 26·5	−3·8	4	3 52 32·44	84 5 46·8	*f*
27 10 29 50	A.D.	+0 54·39	+0·09	−11 23·8	−4·0	5	3 22 26·36	82 27 33·7	*g*

Mean Places of Comparison Stars.

	Star's Name.	R.A. 1885·0. h m s	N.P.D. 1885·0. ° ′ ″	Authority.
a	W.B. (2) XXIII. 1096	23 53 50·46	69 20 57·2	Weisse's Bessel
b	Lalande 46906	23 50 5 58	69 28 29·6	Lalande
c	Arg. Z. + 20° No. 5397	23 50 12·64	69 17 29·6	Bonn. Obs. vol. vi.
d	Arg. Z. + 20° No. 5401	23 51 1·69	69 30 16·8	„ „ „ iv.
e	Arg. Z. + 5° No. 566	3 51 37 67	84 9 8 6	„ „ „ iii.
f	Arg. Z. + 5° No. 572	3 52 24·86	84 11 16·3	„ „ „ iii.
g	W.B. III. 344	3 21 27·95	82 39 3·0	Schjellerup.

Notes.

Dec. 24 (*d*) Comet very faint; no nucleus.
27 (*d*) Comet faint; circular, with very faint nucleus.
15 (*e*) Small round object; no nucleus or tail.
27 (*e*) Faint, with nucleus.

The observations are corrected for parallax and refraction. The initials H.T., A.D., and H. are those of Mr. Turner, Mr. Downing, and Mr. Hollis respectively.

Royal Observatory, Greenwich:
1886, *January* 8.

Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the year 1885. No. IX.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. xxxvi. p. 318, vol. xxxvii. p. 22, vol. xxxviii. p. 493, vol. xli. p. 109, vol. xlii. p. 230, vol. xliii. p. 81, vol. xliv. p. 89, and vol. xlv. p. 330. The observations were made with the "half-prism" spectroscope, one "half-prism" with a dispersion of about $18\frac{1}{2}°$ from A to H being used, except in a few cases of bright stars mentioned in the Remarks, where a train of two "half-prisms," with a dispersion of 80° from A to H, was used. An eyepiece with a magnifying power of 14 was employed throughout.

The cylindrical lens has always been used in front of the slit as in the observations made previously to 1881. A slip of metal coated with Balmain's luminous paint, inserted immediately behind the measuring pointer, has been frequently employed to give a phosphorescent illumination of the field.

The observations of the Moon and of the Sun have been made as a check on the general accuracy of the results.

Motions of Stars in the Line of Sight, in Miles per Second, observed with the Half-prism Spectroscope.

(+ denotes Recession; − Approach.)

The initials M. and N. are those of Mr. Maunder and Mr. Nash respectively.

Date. 1885.	Obs.	No. of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				α Andromedæ.			
Nov. 5	M	2	F	+ 8·7	−23·3	−29·5	Definition poor.
17	M	2	F	+11·6	−38·7	−49·8	Spectrum steady; definition good.
28	M	2	F	+13·8	−35·1	−25·7	
Dec. 1	N	2	F	+14·3	−29·8	−30·7	Slit too narrow for satisfactory work.
8	N	2	F	+15·4	−49·3	−47·8	Spectrum bright and steady; star-line distinct.
15	N	2	F	+16·2	−17·2	−16·2	Spectrum bright and steady; star-line faint.
				γ Pegasi.			
Nov. 17	M	2	F	+13·7	−29·6	−38·5	Spectrum tremulous and faint.
Dec. 8	N	2	F	+17·3	−35·9	−35·6	
15	N	2	F	+18·0	−29·2	−30·2	
				α Cassiopeiæ.			
Oct. 5	M	2	b_1	− 5·0	+55·9	+54·4	Spectrum very tremulous; definition bad.
				β Arietis.			
Nov. 17	M	2	F	+ 7·4	−46·5	−49·8	Star-line diffused, and very broad.
Dec. 1	N	2	F	+11·4	−50·1	−57·2	Spectrum faint; measures difficult.
8	N	2	F	+13·2	−31·1	−31·8	
15	N	2	F	+14·7	−30·0	−30·0	Spectrum faint; measures difficult.
				α Arietis.			
Nov. 17	M	2	F	+ 6·3	− 8·9	−14 8	Star-line very faint, and seen with great difficulty.
Dec. 1	N	2	F	+10·4	−35·5	−42·5	Measures difficult.
	N	2	F	+12·2	−38·2	−38·6	
15	N	2	F	+13·9	− 6·6	− 9·4	
				γ Persei.			
Nov. 17	M	2	F	− 0·7	+67·1	+60·8	Spectrum faint; star-line faint and diffused.

Date. 1885.	Obs.	No. of Meas.	Line.	Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				Rigel.			
Feb. 5	M	2	F	+14·3	+10·6	+ 8·9	Star-line fairly well seen.
7	M	6	F	+14·5	+13·2	+ 8·0	Individual measures discordant.
21	M	2	F	+15·7	+28·5	+21·6	Spectrum very faint; measures rough.
Nov. 5	M	3	F	− 8·3	(−27·2)	(−26·9)	Star-line exceedingly difficult to see. Measures rough.
28	M	2	F	− 2·3	+26·9	+21·5	
Dec. 8	N	2	F	+ 0·5	+23·5	+23·8	Wind very troublesome.
15	N	2	F	+ 2·5	+23·5	+25·0	
				γ Orionis.			
Feb. 5	M	2	F	+15·3	−17·3	−20·0	Spectrum bright and fairly steady.
7	M	4	F	+15·7	−25·9	−31·4	Star-line fairly well seen.
Nov. 5	M	2	F	−10·4	+ 6·9	+ 5·8	Star-line faint; observation difficult.
Dec. 15	N	2	F	+ 1·6	+ 1·9	+ 3·6	
				β Tauri.			
Feb. 5	M	4	F	+15·6	−35·1	−39·6	Star-line diffused and difficult to bisect.
7	M	3	F	+16·0	(−39·8)	(−51·1)	Sky cloudy: measures uncertain.
Nov. 5	M	2	F	−11·2	−26·8	−27·3	Definition fair; measures considered good.
Dec. 8	N	2	F	− 1·2	−37·0	−39·4	
				δ Orionis.			
Feb. 5	M	4	F	+14·4	−23·1	−26·0	Observation very difficult.
				ε Orionis.			
Feb. 5	M	2	F	+14·2	−17·7	−16·6	Spectrum fairly bright and steady.
				ζ Orionis.			
Feb. 5	M	2	F	+13·9	−23·8	−25·5	Star-line fairly well seen by glimpses.
				κ Orionis.			
Feb. 5	M	4	F	+12·6	−24·8	−23·1	Star-line distinctly seen, but difficult to bisect.
				α Orionis.			
Feb. 23	M	2	b_1	+16·7	+21·4	+22·4	Star-line occasionally seen distinctly isolated from the dark band in which it lies.
25	M	2	b_1	+16·9	+12·6	+ 4·5	Spectrum very tremulous

Date. 1885.	Obs.	No. of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				β Persei.			
Feb. 7	M	2	F	+17·4	−45·1	−57·3	Measures difficult and rough.
Nov. 17	M	2	F	+ 0·4	−39·5	−49·9	Spectrum bright and steady; definition good.
Dec. 8	N	2	F	+ 6·7	−19·7	−20·6	
				α Persei.			
Feb. 7	M	2	F	+16·0	−74·8	−87·2	Spectrum and star-line faint; measures rough.
				Aldebaran.			
Feb. 3	M	2	F	+17·3	+ 7·2	+13·1	Star-line faint, but well defined.
5	M	3	F	+17·6	+ 7·7	+10·3	Definition variable.
7	M	2	F	+17·8	+36·3	+42·0	Star-line faint, and only seen by glimpses.
19	M	2	F	+18·5	+27·4	+16·5	Spectrum and star-line faint.
21	M	2	F	+18·6	+33·5	+26·1	Spectrum and star-line faint, observation rough.
23	M	2	b_1	+18·6	+20·8	+14·0	Spectrum very unsteady.
25	M	2	b_1	+18·6	+18·6	+11·0	Spectrum bright; star-line well seen.
Mar. 10	N	2	b_1	+18·1	+41·4	+39·1	Spectrum unsteady; *b* lines sharp and distinct.
12	N	1	b_1	+17·9	+14·8	+17·4	Spectrum faint and tremulous; measures rough.
Nov. 5	M	2	F	− 7·7	+31·9	+38·5	Definition fair; measures considered good.
28	M	2	F	− 0·4	+28·7	+19·6	
Dec. 1	N	2	F	+ 0·6	(−20·5)	(−21·2)	Star-line very faint and indistinct.
8	N	2	F	+ 2·9	+26·6	+26·8	Spectrum tremulous; wind high.
15	N	2	F	+ 5·2	+30·9	+27·8	
				Capella.			
Feb. 7	M	4	F	+14·9	+ 2·7	+ 5·0	Spectrum bright and steady.
23	M	2	b_1	+16·7	+19·4	+16·8	Spectrum bright, but *very* unsteady; wind high.
25	M	2	b_1	+16·8	+13·6	+ 7·5	Spectrum very unsteady; star-lines very faint.
Mar. 10	N	2	b_1	+17·2	− 0·1	− 5·0	Star-line very faint.
12	N	3	b_1	+17·1	+31·2	+32·3	Spectrum bright and fairly steady.
Nov. 5	M	2	F	−10·3	+28·6	+31·0	Definition very good; star-line well seen.

Date. 1885.	Obs.	No. of Meas.	Line.	Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				Rigel.			
Feb. 5	M	2	F	+14·3	+10·6	+ 8·9	Star-line fairly well seen.
7	M	6	F	+14·5	+13·2	+ 8·0	Individual measures discordant.
21	M	2	F	+15·7	+28·5	+21·6	Spectrum very faint; measures rough.
Nov. 5	M	3	F	− 8·3	(−27·2)	(−26·9)	Star-line exceedingly difficult to see. Measures rough.
28	M	2	F	− 2·3	+26·9	+21·5	
Dec. 8	N	2	F	+ 0·5	+23 5	+23·8	Wind very troublesome.
15	N	2	F	+ 2·5	+23·5	+25·0	
				γ Orionis.			
Feb. 5	M	2	F	+15·3	−17·3	−20·0	Spectrum bright and fairly steady.
7	M	4	F	+15·7	−25·9	−31·4	Star-line fairly well seen.
Nov. 5	M	2	F	−10·4	+ 6·9	+ 5·8	Star-line faint; observation difficult.
Dec. 15	N	2	F	+ 1·6	+ 1·9	+ 3·6	
				β Tauri.			
Feb. 5	M	4	F	+15·6	−35·1	−39·6	Star-line diffused and difficult to bisect.
7	M	3	F	+16·0	(−39·8)	(−51·1)	Sky cloudy: measures uncertain.
Nov. 5	M	2	F	−11·2	−26·8	−27·3	Definition fair; measures considered good.
Dec. 8	N	2	F	− 1·2	−37·0	−39·4	
				δ Orionis.			
Feb. 5	M	4	F	+14·4	−23·1	−26·0	Observation very difficult.
				ε Orionis.			
Feb. 5	M	2	F	+14·2	−17·7	−16·6	Spectrum fairly bright and steady.
				ζ Orionis.			
Feb. 5	M	2	F	+13·9	−23·8	−25·5	Star-line fairly well seen by glimpses.
				κ Orionis.			
Feb. 5	M	4	F	+12·6	−24·8	−23·1	Star-line distinctly seen, but difficult to bisect.
				α Orionis.			
Feb. 23	M	2	b_1	+16·7	+21·4	+22·4	Star-line occasionally seen distinctly isolated from the dark band in which it lies.
25	M	2	b_1	+16·9	+12·6	+ 4·5	Spectrum very tremulous

Date. 1885.	Obs.	No. of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				β Aurigæ.			
Feb. 7	M	2	F	+13·6	(−49·8)	(−56·3)	Sky cloudy; measures uncertain.
				γ Geminorum.			
Feb. 5	M	4	F	+12·0	−93·7	−79·4	Very large displacement towards the blue; estimations rough.
				Sirius.			
Feb. 3	M	6	F	+ 7·9	−13·4	−15·2	Star-line exceedingly difficult to bisect; slight displacement towards the blue.
5	M	4	F	+ 8·3	−42·5	−47·1	Displacement towards the blue very marked.
7	M	3	F	+ 8·7	(−71·3)	(−50·4)	Sky cloudy; measures uncertain.
Mar. 14	M	4	F	+13·6	−21·4	−23·4	Slight displacement towards the blue.
14	M	4	F	+13·6	−21·9	−25·9	Two-prism train employed.
27	N	2	F	+14·1	−10·3	− 8·9	Measures difficult.
Nov. 5	M	6	F	−12·3	−20·3	−24·9	Spectrum very bright, but tremulous; star-line very broad and ill-defined; star-line suspected not to be symmetrical.
28	M	6	F	− 8·5	− 8·7	− 7·2	*Small* displacement towards the blue.
Dec. 15	N	2	F	− 4·6	−18·4	−16·8	
				Castor.			
Feb. 3	M	2	F	+ 8·4	−21·8	−25·0	Star-line very ill defined.
Mar. 14	M	4	F	+16·7	−38 9	−41·1	Unmistakable displacement towards the blue.
27	N	3	F	+17·8	− 9·9	−11·6	Star-line broad and diffused.
				Procyon.			
Feb. 3	M	2	F	+ 6·6	−12·6	−17·6	Star-line fairly well seen.
5	M	4	F	+ 7·2	− 0·1	− 1·4	Spectrum bright and steady.
Mar. 14	M	4	F	+15·5	−19·5	−20·2	Star-line unusually well defined.
27	N	2	F	+17·0	−33·9	−33·6	Spectrum tremulous.
Dec. 15	N	4	F	− 9·1	−16·8	−15·3	
				Pollux.			
Feb. 3	M	2	F	+ 7·3	−35·2	−34·9	Star-line very faint and difficult to see.
23	M	2	b_1	+12·7	−17·2	−18·3	Star-line exceedingly faint.

Date. 1885.	Obs.	No. of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
Feb. 25	M	2	b_1	+13·1	−33·4	−40·0	Spectrum very unsteady; star-line fairly dark and distinct.
Mar. 11	M	2	b_1	+15·9	−25·9	−30·2	Spectrum tremulous; star-line fairly well seen.
14	M	4	F	+16·3	−25·6	−24·7	Star-line faint.
Apr. 21	M	2	b_1	+17·8	−23·3	−27·5	Spectrum bright, but very tremulous.
					α Hydræ.		
Feb. 23	M	2	b_1	+ 3·0	+ 8·8	+ 8·2	Star-line seen with the greatest difficulty; measures very rough.
Mar. 11	M	2	b_1	+ 7·5	+ 5·5	+ 6·8	Spectrum faint and tremulous; definition fair.
					Regulus.		
Mar. 14	M	2	F	+ 8·3	−15·7	−20·2	Star-line fairly well defined.
Apr. 18	M	2	F	+15·9	+ 6·9	+ 3·0	Definition exceedingly bad.
					γ Leonis.		
Mar. 11	M	2	b_1	+ 7·4	+23·0	+23·2	Star-line faint, but seen well by glimpses.
					α Ursæ Majoris.		
Aug. 14	M	1	F	− 1·7	− 3·4	− 5·7	Spectrum faint; definition poor.
					β Leonis.		
Mar. 14	M	4	F	+ 1·4	−16·5	−14·4	Star-line dark, very broad and ill defined at edges; displacement evidently small.
					δ Ursæ Majoris.		
Aug. 10	M	2	F	+ 2·1	+30·1	+29·4	Star-line broad and ill defined; observations very difficult.
					ε Ursæ Majoris.		
Aug. 10	M	4	F	+ 3·4	−41·7	−41·1	Definition fair; observation difficult.
					ε Virginis.		
Mar. 11	M	2	b_1	− 5·1	+ 7·6	+ 6·8	Star-line very difficult to see.
Apr. 29	M	2	b_1	+ 9·1	−18·0	−22·5	Star-line faint and difficult to see.
					Spica.		
Mar. 14	M	2	F	− 8·6	−25·5	−28·1	Star-line faint and very badly defined; measures very rough.
					ζ Ursæ Majoris.		
Aug. 10	M	2	F	+ 4·2	+34·6	+32·9	Both stars observed as one; definition fair.

Date. 1885.	Obs.	No. of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				η Ursæ Majoris.			
Aug. 10	M	4	F	+ 6·2	+14·6	+15·7	Small displacement towards the red.
				α Draconis.			
Aug. 10	M	4	F	+ 2·1	+34·9	+35·0	Star-line broad and diffused at edges.
				Arcturus.			
Mar. 11	M	2	b_1	− 8·2	−12·5	−13·5	Spectrum bright, but tremulous; star-line faint.
14	M	2	F	− 7·5	−46·7	−52·8	Star-line faint; definition poor.
Apr. 29	M	2	b_1	+ 4·6	−35·8	−40·2	Spectrum exceedingly tremulous; definition bad.
May 7	N	2	b_1	+ 6·6	−70·3	−74·1	Spectrum faint; cloudy.
29	N	3	b_1	+11·1	−48·3	−50·9	Star-line faint; measures difficult.
June 2	N	2	F	+11·8	−36·7	−35·2	Star-line very faint.
2	N	2	F	+11·8	−42·0	−43·5	Definition much improved.
18	N	2	F	+13·9	−47·5	−46·0	Measures considered good.
July 9	M	2	F	+15·2	−52·1	−43·1	Spectrum tremulous; definition bad.
				α Coronæ Borealis.			
July 9	M	2	F	+11·7	+ 4·9	− 0·5	Spectrum faint; definition bad.
Aug. 17	M	2	F	+12·4	−11·8	−12·4	Star-line very broad, but the edges of the line are sharper than in many stars of the type; measures discordant.
				ζ Draconis.			
Aug. 10	M	2	F	+ 1·1	−46·1	−44·4	Spectrum faint, but steady.
				α Ophiuchi.			
June 18	N	2	F	+ 1·8	−38·4	−37·9	Displacement towards the blue appeared certain.
July 9	M	2	F	+ 6·6	−39·9	−34·6	Spectrum faint; definition poor.
23	N	2	F	+ 9·4	−30·5	−32·2	Star-line faint; measures doubtful.
				Vega.			
May 29	N	2	F	− 4·8	(− 7·4)	(− 6·8)	Measures doubtful.
July 9	M	2	F	+ 0·6	−32·1	−28·5	Spectrum bright but tremulous.
Aug. 3	M	2	F	+ 4·0	−33·9	−34·9	Definition variable.
5	M	2	F	+ 4·2	−42·9	−41·3	Spectrum faint; definition fair.
10	M	2	F	+ 4·8	−54·6	−53·0	Star-line very broad and diffused.

Date 1885.	Obs.	No. of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
Aug. 17	M	2	F	+ 5·6	−26·9	−27·2	Definition good.
25	M	2	F	+ 6·5	−35·5	−37·5	Definition fair.
27	M	2	F	+ 6·6	−19·5	−21·1	Spectrum tremulous.
29	M	2	F	+ 6·8	−38·1	−37·8	Spectrum bright and steady.
Nov. 5	M	4	F	+ 7·7	−34·2	−37 8	Cloudy; definition poor; observation difficult.
17	M	2	F	+ 6·6	−38·8	−53·2	Spectrum bright, but very unsteady.
18	N	2	F	+ 6·5	−44·3	−43·4	
					ζ Aquilæ.		
Nov. 17	M	4	F	+12·0	−25·0	−23·7	Spectrum very faint and tremulous; measures very difficult.
					Altair.		
July 9	M	2	F	− 3·3	−45·0	−38·6	Spectrum fairly steady.
23	N	2	F	+ 0 3	− 4·7	− 4·9	Star-line broad.
Aug. 3	M	2	F	+ 3·2	−50 6	−40·3	Spectrum faint; observation difficult; large displacement towards the blue.
25	M	2	F	+ 8·5	−50·1	−49·8	Definition fair.
29	M	2	F	+ 9·4	−36·0	−38·3	Cloudy; spectrum steady.
Nov. 17	M	2	F	+14·8	−73·6	−64·3	Spectrum very tremulous.
18	N	2	F	+14·7	−35·5	−35·3	Star-line diffused; measures difficult and doubtful.
					γ Cygni.		
Nov. 17	M	2	F	+10 2	−11·7	−12·0	Spectrum fairly steady; definition good.
					α Cygni.		
July 9	M	2	F	− 6·4	−35·4	−29·0	Spectrum steady; definition good.
Aug. 25	M	2	F	− 0·1	−30·5	−33·0	Spectrum steady; definition fair.
Sept. 26	M	2	b_1	+ 4·6	−67·7	−68·2	Spectrum very tremulous; definition bad.
Nov. 17	M	2	F	+ 9·3	−40·9	−40·4	Spectrum steady; definition good.
18	N	2	F	+ 9·4	−40·6	−40·2	
					ε Cygni.		
Nov. 17	M	5	F	+12·2	+ 7·1	+ 2·3	Spectrum steady; star-line faint.
					α Cephei.		
Aug. 25	M	2	F	− 4·0	−17·3	−20·8	Spectrum faint, but steady; measures difficult.
Nov. 17	M	2	F	+ 4·7	−33·0	−40·1	Spectrum steady; definition fair.

Date. 1885.	Obs.	No. of Line. Meas.		Earth's Motion in M. per sec.	Concluded Motion of Star. Meas.	Estimd.	Remarks.
				β Pegasi.			
Oct. 5	M	2	b_4	+ 4·1	−31·9	−30·6	Spectrum bright, but tremulous; the b_1 lines could not be isolated from the shaded band in which they lie.
				α Pegasi.			
July 23	N	2	F	−13·0	−18·5	−20·4	Spectrum faint; star-line indistinct; measures doubtful.
Aug. 25	M	2	F	− 5·5	+ 8·8	+ 7·3	Spectrum faint, but steady; definition fair.
Nov. 17	M	2	F	+15·9	−23·7	−28·6	Definition fair.
Dec. 15	N	2	F	+17·9	− 3·6	− 5·7	Star-line broad and dark.

Moon.

Date.	Obs.	No. of Meas.	Line.	Motion Measured.	Remarks.
Feb. 3	M	5	F	− 3·1	
19	M	5	F	−11·6	Measures discordant.
21	M	5	F	−10·3	Coincidence appeared perfect; measures discordant
23	M	5	b_1	− 2·1	Coincidence appeared perfect.
25	M	5	b_1	− 3·5	Coincidence appeared perfect.
Mar. 27	N	4	F	− 1·1	
Apr. 21	M	5	b_1	− 1·6	
29	M	5	b_1	− 1·6	Coincidence appeared perfect.
May 29	N	4	b_1	− 2·0	Coincidence appeared perfect.
July 23	N	4	F	+ 2·6	Coincidence appeared perfect.
Aug. 25	M	5	F	− 4·1	Coincidence appeared perfect.
Nov. 17	M	5	F	− 2·8	Coincidence appeared perfect.
18	N	4	F	− 1·5	Coincidence appeared perfect.
Dec. 15	N	4	F	+ 1·4	Coincidence appeared perfect.

Sun.

Nov. 6	M	5	F	− 0·4	

Venus.

Oct. 16	M	15	b_1	−14·0	−7·8 Computed Motion −7·4.

Rotation of Jupiter.

Displacement between the *p* and *f* limbs.

				p−*f*.	
Apr. 21	M	5	b_1	+31·6	Position Circle Reading 207° 30′; slit tangential to the planet's limb, the outer edge of the slit being placed exactly on the limb; cylindrical lens before the slit.

Date.	Obs.	No. of Meas.	Line.	Motion Measured.	Remarks.
Apr. 21	M	5	b_1	+20·4	Position Circle Reading 117° 30′; slit radial; no cylindrical lens.
27	M	2	b_1	+28·8	Position Circle Reading 207° 30′; slit tangential, the outer edge of the slit being placed exactly on the limb; cylindrical lens before the slit.
29	M	3	b_1	+17·2	
29	M	3	b_1	+30·7	Position Circle Reading 27° 30′; slit tangential; cylindrical lens before the slit.

Displacement between the *n* and *s* limbs.

				$n-s$.	
Apr. 29	M	3	b_1	− 0·4	Position Circle Reading 117° 30′.
29	M	3	b_1	− 2·0	Position Circle Reading 297° 30′; slit tangential at both positions, the outer edge of the slit being placed exactly on the limb; cylindrical lens before slit.

Computed relative motion of the *p* and *f* limbs 30·9 miles per second, the equatorial diameter of *Jupiter* being taken as 88,000 miles, and its period of rotation as $9^h\ 56^m$.

Rotation of Saturn's Rings.

Displacement between the *p* and *f* ansæ.

				$p-f$.	
Apr. 21	M	10	b_1	+26·7	Position Circle Reading 180° 0′; the inner edge of the slit was placed on the Cassinian division. Lines very faint and difficult to see. It was not found possible to observe the relative displacement of lines from the *p* and *f* limbs of the planet.

Computed Relative motion of the ansæ 19·4 miles per second, the diameter of the outer ring being taken as 170,000 miles, and the point observed being assumed to be 1″·5 from the extremity of the major axis of the ring.

Observations of Occultations of Stars and Uranus by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1885.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars and Uranus by the Moon.

Day of Obs.		Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
							h m s	
1885, Feb.	20 (*a*)	Disapp.	38 Arietis	Simms' Eq.	220	Dark	7 40 37·53	H. T.
	20	,,	38 Arietis	Altaz	100	,,	7 40 37·57	A. D.
	20 (*a*)	,,	38 Arietis	E. Eq.	70	,,	7 40 37·59	H.
	23 (*a*)	,,	130 Tauri	Altaz	100	,,	11 2 21·94	H. T.
	23	,,	130 Tauri	E. Eq.	140	,,	11 2 21·54	T.
Mar.	22	,,	W. B. (2) V. 445	Simms' Eq.	220	,,	6 48 38·77	H. T.
	22	,,	111 Tauri	,,	,,	,,	6 51 33·07	,,
	22	,,	111 Tauri	Altaz	100	,,	6 51 32·54	T.
	22	,,	111 Tauri	E. Eq.	210	,,	6 51 32·44	H.
	22	,,	117 Tauri	Lassell Refl.	250	,,	9 2 33·95	W. C.
	22	,,	117 Tauri	Simms' Eq.	220	,,	9 2 34·37	H. T.
	22	,,	117 Tauri	Altaz	100	,,	9 2 34·01	T.
	27 (*b*)	,,	B. F. 1464	Lassell Refl.	250	,,	10 23 28·61	H. T.
	27 (*c*)	,,	B. F. 1464	Simms' Eq.	220	,,	10 23 28·15	C.
	27	,,	43 Leonis	Altaz	100	,,	11 36 26·08	H. T.
	27	,,	43 Leonis	Simms' Eq.	220	,,	11 36 25·72	C.
	27	,,	43 Leonis	E. Eq.	210	,,	11 36 25·98	A. D.

Day of Obs.		Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
							h m s	
1885. Mar.	28 (*d*)	Disapp.	B. F. 1589	E. Eq.	210	Dark	10 18 40·00	T.
	28	,,	75 Leonis	Simms' Eq.	220	,,	12 13 38·84	H. T.
	28	,,	75 Leonis	E. Eq.	210	,,	12 13 38·14	T.
	28	,,	75 Leonis	Altaz	100	,,	12 13 38·54	L.
	31 (*e*)	Reapp.	B. F. 1886	,,	,,	Bright	10 27 50·47	W. C.
Apr.	20 (*f*)	Disapp.	Anonyma	Simms' Eq.	220	Dark	10 26 2·72	H. T.
	20	,,	λ Geminorum	,,	,,	,,	10 58 57·73	,,
	20	,,	λ Geminorum	Altaz	100	,,	10 58 57·44	T.
	20	,,	λ Geminorum	E. Eq.	210	,,	10 58 57·62	L.
	20 (*g*)	Reapp.	λ Geminorum	Simms' Eq.	220	Bright	11 20 18·73	H. T.
	20 (*h*)	,,	λ Geminorum	Altaz	100	,,	11 20 25·32	T.
	20 (*i*)	,,	λ Geminorum	E. Eq.	210	,,	11 20 22 82	L.
July	20 (*j*)	Disapp.	o^2 Libræ	Altaz	100	Dark	10 57 0·92	H.
	22	,,	29 Ophiuchi	,,	,,	,,	10 31 57·29	A. D.
	22	,,	29 Ophiuchi	E. Eq.	210	,,	10 31 56·99	H.
Aug.	20	,,	Piazzi XVIII. 82	,,	,,	,,	11 38 47·25	,,
Sep.	1	Reapp.	θ^2 Tauri	,,	,,	,,	10 51 57·27	H. T.
	1 (*k*)	,,	θ^2 Tauri	Altaz	100	,,	10 51 57·41	S. D.
	1	,,	Bradley 619	E. Eq.	70	,,	11 32 17·14	H. T.
	1 (*k*)	,,	Bradley 619	Altaz	100	,,	11 32 17·01	S. D.
	1	,,	85 Tauri	E. Eq.	70	,,	12 0 33·25	H. T.

Day of Obs.	Phenomenon.		Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1885, Sep. 19 (*k*)	Disapp.	13 Capricorni	E. Eq.	210	Dark	8 4 9·90	A. D.
20	,,	18 Aquarii	,,	,,	,,	6 48 32·71	H. T.
21	,,	Bradley 2930	Simms' Eq.	220	,,	10 7 44·97	A. D.
25 (*l*)	,,	μ Piscium	E. Eq.	,,	Bright	8 11 25·50	L.
Oct. 1 (*k*)	,,	λ Geminorum	Altaz	100	,,	12 38 14·33	A. P.
1 (*k*)	,,	λ Geminorum	E. Eq.	210	,,	12 38 16·22	R. W.
Nov. 17	,,	Piazzi XXIII. 270	,,	,,	Dark	10 40 37·17	L.
30	,,	Uranus 1 L	,,	70	Bright	16 59 34·75	,,
30 (*m*)	,,	Uranus 2 L	,,	,,	,,	16 59 35 55	,,
30	Reapp.	Uranus 1 L	,,	,,	Dark	18 9 26·17	,,
30 (*n*)	,,	Uranus 2 L	,,	,,	,,	18 9 27 07	,,
Dec. 28 (*l*)	Disapp.	θ Virginis	Altaz	100	Bright	16 5 38·55	J. P.
28 (*o*)	Reapp.	θ Virginis	Lassell Refl.	350	Dark	17 14 50 76	H. T.
28	,,	θ Virginis	Altaz	100	,,	17 14 46·40	J. P.

Notes.

(*a*) Disappearance instantaneous.
(*b*) Star much fainter than expected.
(*c*) Observation doubtful owing to difficulty in keeping the faint star steadily in view; telescope shaken by wind.
(*d*) Star very faint; Moon very bright.
(*e*) Observation doubtful, star's light overpowered by that of the Moon.
(*f*) Angle from vertex about 70°; star 6th or 7th magnitude.
(*g*) Reappearance instantaneous.
(*h*) Probably late.
(*i*) Observation good.
(*j*) Star very faint; observation considered unsatisfactory.
(*k*) Cloudy.
(*l*) Limb very unsteady.
(*m*) The planet seemed to take about 1 sec. to disappear.
(*n*) Dark limb of Moon very distinct.
(*o*) Probably too late; the star reappeared very near the edge of the field.

Phenomena of Jupiter's Satellites.

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1885, Jan. 4 (*a*)	III.	Occ. D.	First contact	E. Eq.	140	11 22 36	11 25	L.
			Last seen	,,	,,	11 28 11		
	III.	Occ. R.	Bisection	,,	,,	14 59 36	15 0	H. T.
8	IV.	Tr. Ing.	First contact	Simms' Eq.	220	14 1 1		,,
(*b*)			Bisection	,,	,,	14 4 46		,,
			Last contact	,,	,,	14 6 41		,,
			First contact	E. Eq.	140	14 1 20	14 12	L.
			Bisection	,,	,,	14 4 19		,,
			Last contact	,,	,,	14 6 49		,,
(*c*)	IV.	Tr. Egr.	Last contact	Simms' Eq.	220	18 50 42	18 43	H. T.
20	II.	Occ. R.	Bisection	,,	,,	11 14 8		,,
			Last contact	,,	,,	11 15 53		,,
(*d*)			First seen.	E. Eq.	210	11 13 35	11 15	T.
			Last contact	,,	,,	11 14 50		,,
25	IV.	Tr. Egr.	First contact	,,	,,	9 28 55		A. D.
			Last contact	,,	,,	9 37 24	9 40	,,
			Last contact	Simms' Eq.	220	9 37 56		L.
27	II.	Occ. R.	First seen	E. Eq.	140	13 30 37	13 33	,,
			Last contact	,,	,,	13 34 51		

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Powe	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						m s	h m s	
1885, Jan. 29 (*e*)	III.	Tr. Ing.	First contact	E. Eq.	210	11 16 34	11 19	A.D.
Feb. 2 (*f*)	I.	Tr. Ing.	Bisection	,,	140	12 13 49	12 12	J. P.
			Last contact	,,	,,	12 15 34		
3	I.	Occ. R.	Last contact	,,	210	11 42 12	11 41	H. T.
(*g*)	II.	Ec. D.	Last seen	,,	,,	13 8 12	12 9 27	,,
5	II.	Tr. Egr.	First contact	,,	,,	9 59 34		
			Bisection	,,	,,	10 2 48	10 8	B.
			Last contact	,,	,,	10 5 48		
9 (*h*)	III.	Occ. R.	First seen	Simms' Eq.	220	7 50 57		W. C.
			Bisection	,,	,,	7 52 27		,,
			Last contact	,,	,,	7 55 57		,,
(*i*)			First seen	Altaz	100	7 51 43		H. T.
			Last contact	,,	,,	7 58 31	7 53	,,
(*j*)			First seen	S.E. Eq.	220	7 50 3		M.
			Bisection	,,	,,	7 54 8		,,
			Last contact	,,	,,	7 59 7		,,
(*k*)			Last contact	E. Eq.	210	7 54 22		T.
11 (*l*)	I.	Tr. Egr.	First contact	,,	,,	10 37 1		H. T.
			Bisection	,,	,,	10 39 40	10 41	
			Last contact	,,	,,	10 42 50		

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1885, Feb. 18	I.	Tr. Ing.	Last contact	Simms' Eq.	220	10 9 48		"
			First contact	E. Eq.	210	10 3 47	10 6	L.
			Bisection	"	"	10 5 57		"
			Last contact	"	"	10 8 16		"
	I.	Tr. Egr.	First contact	"	"	12 21 20		
			Bisection	"	"	12 23 44	12 25	"
			Last contact	"	"	12 25 49		
19 (*d*)	IV.	Ecl. R.	First seen	Lassell Refl.	145	8 44 42		W. C.
			First seen	Simms' Eq.	220	8 45 3		H. T.
(*m*)			First seen	S.E. Eq.	310	8 44 13		M.
			Bisection	"	"	8 49 23		"
			Full brightness	"	"	8 53 43	8 41 52	"
(*d*)			First seen	E. Eq.	210	8 46 2		T.
(*n*)			First seen	Altaz	100	8 45 10		L.
			Full brightness	"	"	8 49 9		"
23 (*o*)	III.	Occ. D.	First contact	"	"	10 43 10		H. T.
			Bisection	"	"	10 47 59		"
			Last seen	"	"	10 52 14		"
(*o*)			First contact	E. Eq.	70	10 43 24	10 49	T.
			Last seen	"	140	10 54 7		"
			First contact	Simms' Eq.	220	10 44 24		L.
			Last seen	"		10 52 54		"

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1885, Feb. 23 (*o*)	III.	Ecl. R.	First seen	E. Eq.	140	14 51 58	14 49 46	T.
25	I.	Tr. Ing.	First contact	Lassell Refl.	170	11 47 36		H. T.
			Last contact	,,	,,	11 51 51		,,
			First contact	E. Eq.	140	11 47 51	11 50	L.
			Bisection	,,	,,	11 50 6		,,
			Last contact	,,	,,	11 52 35		,,
	I.	Tr. Egr.	First contact	,,	,,	14 6 13	14 9	,,
			Last contact	,,	,,	14 11 42		
	I.	Sh. Egr.	First contact	,,	,,	14 15 12	14 19	,,
			Last contact	,,	,,	14 18 26		
Mar. 2 (*p*)	III.	Occ. D.	First contact	,,	210	14 3 31		
			Bisection	,,	,,	14 8 40	14 6	H. T.
			Last seen	,,	,,	14 11 30		
4	I.	Tr. Ing.	First contact	,,	,,	13 32 5	13 34	H.
			Last contact	,,	,,	13 34 28		
	I.	Tr. Egr.	First contact	,,	,,	15 49 6	15 54	L.
			Last contact	,,	,,	15 54 20		
	I.	Sh. Egr.	First contact	,,	,,	16 8 18	16 14	,,
			Last contact	,,	,,	16 11 18		

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1885, Mar. 7 (*e*)	I.	Ecl. R.	First seen	Simms' Eq.	220	7 49 31		L.
			Full brightness	,,	,,	7 52 23		,,
(*e*)			First seen	E. Eq.	210	7 51 21	7 49 4	A. P.
			Full brightness	,,	,,	7 54 21		,,
14	I.	Ecl. R.	First seen	,,	,,	9 43 28	9 43 20	A. D.
			Full brightness	,,	,,	9 45 35		
(*q*)	II.	Occ. D.	First contact	,,	,,	13 17 30	13 21	,,
			Last seen	,,	,,	13 21 59		
16	II.	Tr. Egr.	First contact	T. C.	200	10 23 57	10 24	S. D.
20 (*r*)	III.	Tr. Ing.	First contact	E. Eq.	210	10 20 25		T.
			Bisection	,,	,,	10 24 40		,,
			Last contact	,,	,,	10 29 54		,,
(*r*)			First contact	Simms' Eq,	220	10 19 16	10 24	H.
			Bisection	,,	,,	10 23 40		,,
			Last contact	,,	,,	10 28 26		,,
	I.	Tr. Ing.	First contact	E. Eq.	210	11 28 39		
			Bisection	,,	,,	11 31 29	11 31	T.
			Last contact	,,	,,	11 34 13		
(*o*)	I.	Tr. Egr.	First contact	Simms' Eq.	220	13 47 26	13 51	H. T.
			Last contact	,,	,,	13 51 46		

Day of Obs.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1885, Mar. 20 (*s*)	III.	Tr. Egr. First seen	Simms' Eq.	220	13 55 31		
		Bisection	,,	,,	13 57 1	14 2	,,
		Last contact	,,	,,	14 0 46		
23	II.	Tr. Ing. First contact	E. Eq.	210	9 45 0		A. D.
		Last contact	,,	,,	9 51 14		,,
		First contact	Simms' Eq.	220	9 47 12	9 46	L.
		Last contact	,,	,,	9 50 37		,,
27	I.	Tr. Ing. First contact	,,	,,	13 16 17		H.T.
		Bisection	,,	,,	13 18 12		,,
		Last contact	,,	,,	13 21 27	13 18	,,
		First contact	E. Eq.	210	13 14 29		A.D.
		Bisection	,,	,,	13 17 59		,,
		Last contact	,,	,,	13 20 58		,,
(*o*)	III.	Tr. Ing. First contact	Simms' Eq.	220	13 46 27		H. T.
		Bisection	,,	,,	13 50 12		,,
		Last contact	,,	,,	13 55 42	13 50	,,
(*t*)		First contact	E. Eq.	210	13 47 9		A. D
		Bisection	,,	,,	13 49 53		,,
		Last contact	,,	,,	13 54 23		,,
28	I.	Occ. D. First contact	,,	,,	10 25 1		
		Bisection	,,	,,	10 26 31	10 25	T.
		Last seen	,,	,,	10 27 46		

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1885, Mar. 30	I.	Ecl. R.	First seen	E. Eq.	210	8 1 5	8 0 54	H.
			Full brightness	,,	,,	8 2 59		
(*u*)	II.	Tr. Ing.	First contact	,,	,,	12 4 54	12 6	,,
			Last contact	,,	,,	12 8 59		
31 (*p*)	III.	Ecl. R.	First seen	Lassell Refl.	250	10 42 13	10 41 50	W. C.
			Full brightness	,,	,,	10 48 58		,,
			First seen	E. Eq.	210	10 42 49		A. D.
			Full brightness	,,	,,	10 47 12		,,
Apr. 14	I.	Tr. Egr.	First contact	Simms' Eq.	220	8 5 10	8 9	H. T.
			Bisection	,,	,,	8 7 55		
			Last contact	,,	,,	8 9 10		
(*r*)	III.	Occ. D.	First contact	Altaz	100	10 37 30	10 43	,,
(*r*)			First contact	Simms' Eq.	220	10 39 18		L.
17 (*o*)	II.	Tr. Egr.	Last contact	E. Eq.	210	9 2 48	9 2	H.
18 (*v*)	IV.	Tr. Egr.	First contact	,,	,,	11 31 52	11 36	T.
			Bisection	,,	,,	11 37 51		
			Last contact	,,	,,	11 42 50		
20	I.	Occ. D.	First contact	Simms' Eq.	220	10 17 48	10 19	H. T.
			Bisection	,,	,,	10 19 13		,,
			Last seen	,,	,,	10 21 31		,,
			First contact	E. Eq.	210	10 16 57		L.
			Last seen			10 21 22		,,

Day of Obs.	Satellite.	Phenomenon.		Telescope.	ower.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1885. Apr. 21	I.	Tr. Egr.	First contact	E. Eq.	210	9 55 59	9 59	H.
27	IV.	Ecl. R.	First seen	Lassell Refl.	250	8 35 5	8 35 43	A. D.
			Full brightness	„	„	8 41 43		„
			First seen	E. Eq.	210	8 35 59		T.
29	I.	Ecl. R.	First seen	„	„	10 8 51	10 8 58	A. D.
			Full brightness	„	„	10 10 46		
May 1	II.	Tr. Ing.	First contact	„	„	11 3 35	11 5	T.
			Bisection	„	„	11 7 14		
			Last contact	„	„	11 10 59		
9 (*w*)	III.	Tr. Ing.	First contact	„	„	11 51 59	11 56	J. P.
			Bisection	„	„	11 57 38		
			Last contact	„	„	12 2 8		
13	IV.	Occ. D.	Bisection	„	„	9 55 46	9 58	A. D.
			Last contact	„	„	9 59 15		„
(*x*)			Last contact	S.E. Eq.	310	9 57 44		M.
			First contact	Simms' Eq.	220	9 51 54		H.
			Bisection	„	„	9 54 32		„
			Last seen	„	„	9 58 22		„

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1885. May 13	I.	Occ. D.	First contact	E. Eq.	210	10 21 41		A. D.
			Bisection	,,	,,	10 24 11		,,
			Last seen	,,	,,	10 26 56		,,
			First contact	S.E. Eq.	310	10 22 29		M.
			Bisection	,,	,,	10 25 14	10 25	,,
			Last seen	,,	,,	10 27 39		,,
			First contact	Simms' Eq.	220	10 24 13		H.
			Bisection	,,	,,	10 25 57		,,
			Last seen	,,	,,	10 27 34		,,
	III.	Ecl. R.	First seen	E. Eq.	210	10 36 51		A. D.
			Full brightness	,,	,,	10 41 8		,,
(j)			First seen	S.E. Eq.	310	10 36 24		M.
			Bisection	,,	,,	10 38 9	10 35 42	,,
			Full brightness	,,	,,	10 39 44		,,
			First seen	Simms' Eq.	220	10 36 53		H.
			Full brightness	,,	,,	10 39 46		,,
May 20	III.	Ecl. D.	Last seen	E. Eq.	210	11 13 10	11 10 36	T.
22	I.	Ecl. R.	First seen	,,	,,	10 22 53	10 22 55	A. D.
			Full brightness	,,	,,	10 24 17		

Day of Obs.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1885, May 27 (*e*)	III.	Occ. D.	First contact	E. Eq.	210	9 54 15	9 57	H.
			Bisection	,,	,,	9 56 11		
			Last seen	,,	,,	9 58 1		
June 2 (*y*)	II.	Tr. Ing.	First contact	Simms' Eq.	220	10 48 46	10 50	H. T.
			Bisection	,,	,,	10 50 1		,,
			Last contact	,,	,,	10 53 36		,,
(*u*)			Last contact	Lassell Refl.	75	10 51 19		H.
13	I.	Tr. Ing.	First contact	Altaz	100	9 55 0	10 0	A. D.
			Last contact	,,	,,	10 0 9		,,
(*k*)			Last contact	E. Eq.	210	9 59 37		T.
Nov. 16 (*z*)	II.	Tr. Ing.	First contact	Lassell Refl.	350	16 30 53	16 35	H. T
			Last contact	,,	,,	16 35 8		
Dec. 28 (*u*)	III.	Ecl. D.	Began to fade	,,	,,	14 31 9	14 31 54	,,
			Bisection	,,	,,	14 34 54		
			Last seen	,,	,,	14 36 24		
(*z*)	I.	Tr. Ing.	First contact	,,	,,	17 26 16	17 31	,,
			Bisection	,,	,,	17 28 21		
			Last contact	,,	,,	17 32 56		
	III.	Ecl. R.	First seen	,,	,,	17 32 41	17 31 49	,,
			Full brightness	,,	,,	17 42 31		

Notes.

(*a*) Very faint; cloudy. (*b*) Bisection considered a little late.

(*c*) Observation doubtful; frost on lenses made satellite almost invisible. (*d*) Hazy.

(*e*) Cloudy; observation uncertain. (*f*) Satellite distinctly visible on *Jupiter's* disc 6^{m} 15^{s} after last contact.

(*g*) Not a very good observation. Hazy; cloud in the neighbourhood.

(*h*) Definition bad; limb boiling; observation very rough. The satellite appeared to be quite clear of the planet 1^{m} after time of last contact. (*i*) Definition bad; satellite clear of the planet at 8^{h} 2^{m}.

(*j*) Images very unsteady; definition bad. Limb of *Jupiter* very tremulous. The first phase was the best observed; the other times are rough. (*k*) Very diffused.

(*l*) Definition fair. Satellite quite clear of the planet at 10^{h} 44^{m}.

(*m*) The satellite reappeared much closer to the planet than had been expected. The phenomenon was scarcely distinguishable from an occultation. The satellite was, therefore, not noticed until it had obtained some degree of brilliancy. A faint projection of the limb of the planet (as in an occultation) had been seen some little time previously, but no notice had been taken of it, as the satellite was expected to reappear some appreciable distance from the planet. The first glimpse of it would probably be about 45^{s} to 50^{s} earlier than the first time recorded. The second and third times are worth very little. (*n*) Probably late, as the satellite was so very faint and near planet.

(*o*) Definition not good. (*p*) Definition fair. (*q*) Very tremulous. (*r*) Cloudy.

(*s*) Definition bad; cloudy. (*t*) First contact a little uncertain.

(*u*) Observation not considered satisfactory. Limb of planet ill-defined. (*v*) Hazy. Planet ill-defined.

(*w*) Observation difficult. *Jupiter* very tremulous and ill-defined.

(*x*) The observer was unable to use the driving clock, and in consequence of difficulty in keeping. the telescope on the planet, he missed first part of observation. Satellite IV. was distinctly seen after last contact; so also Satellite I., but less distinctly. The appearance in both cases was exactly similar to that seen in a transit, just as the satellite is wholly within the limb. The observer was not quite sure that the whole of Satellite IV. was seen, but by far the greater part was visible. That part of the limb of the satellite nearest the centre of the planet was faint and indistinct, and could not quite be traced; of Satellite I. less could be seen than of Satellite IV.

(*y*) Definition bad, planet low down. (*z*) Definition bad.

Phenomena of the Satellites of Jupiter and Saturn, and Occultations of Stars by the Moon, observed at Mr. Edward Crossley's Observatory, Bermerside, Halifax, in the year 1885, with the 9½-inch Cooke Refractor.

By Joseph Gledhill, F.R.A.S.

Phenomena of Jupiter's Satellites.

(Power 240.)

Date.	Satellite.	Phenomena.	G.M.T. h m s	N.A. h m s	Remarks.
1885, Feb. 2	IV.	Ec. D. Fading?	10 1 0	10 8 28	Poor definition.
		Fading	10 3 0		
		Half gone	10 6 30		
		Last seen	10 10 30		
	I.	Sh. I. Just within	11 50 0	11 48 0	
	I.	Tr. I. First contact	12 11 30	12 12 0	
		Bisection	12 13 30		
		Inner contact	12 15 30		
3	I.	Ec. D. Fading?	9 0 0	9 1 54	Misty.
		Fading	9 1 0		
		Just gone	9 2 30		
	I.	Oc. R. Bisection	11 40 0	11 4 1	E. C. at telescope.
	II.	Ec. D. Last seen	12 9 55	12 9 27	
4	I.	Sh. E. On disc	8 42 0	8 37 0	Bad sky.
	I.	Tr. E. Just off	8 59 0	8 57 0	
5	II.	Sh. E. Just off	9 30 0	9 28 0	

Date.	Satellite.	Phenomena.	G.M.T. h m s	N.A. h m s	Remarks.
	II.	Tr. E. Outer contact	10 10 0	10 8 0	
1885, Feb. 9	III.	Oc. R. „ „	7 56 0	7 53 0	
17	I.	Ec. D. Last seen	12 50 5	12 49 16	Some cloud.
	II.	Ec. D. „ „	17 23 10	17 22 29	Some cloud.
18	I.	Sh. I. Just within	10 7 0	10 5 0	Shadow not seen.
	I.	Tr. I. „ „	10 7 0	10 6 0	
	I.	Tr. E. Just off	12 27 0	12 25 0	Bad sky.
19	IV.	Ec. R. First seen	8 41 30	8 41 52	
	I.	Oc. R. Outer contact	9 35 0	9 34 0	
	II.	Tr. I. „ „	11 39 0	11 38 0	
		Just within	11 41 0		
20	I.	Tr. E. Inner contact	6 49 0	6 51 0	
		Outer contact	6 52 0		
25	I.	Tr. I. On disc	11 57 0	11 50 0	Too late at telescope.
	I.	Tr. E. Outer contact	14 10 0	14 9	Cloudy.
27	I.	Tr. E. Inner contact	8 31 0	8 35	E. C. at telescope.
		Bisection	8 32 30		
		Outer contact	8 34 0		
	I.	Sh. E. Inner contact	8 45 0	8 48	
		Bisection	8 46 0		
	IV.	Tr. I. First contact	9 33 0	9 38 0	The satellite was nearly as dark as a shadow after $10^h\ 30^m$.
		Second contact	9 38 0		

Date.	Satellite.	Phenomena.	G.M.T. h m s	N.A. h m s	Remarks.
1885, Feb. 27	IV.	Sh. I. Just within	11 31 0	11 34 0	
28	II.	Oc. D. First contact	8 45 0	8 48 0	Fair sky.
		Half gone	8 48 0		
		Just gone	8 50 0		
	II.	Ec. R. First seen	12 9 56	12 10 5	
		Half disc?	12 13 0		
		Full?	12 15 0		
Mar. 6	III.	Tr. E. First contact	7 13 0	7 19 0	Fair definition.
		Half off	7 15 0		
		Outer contact	7 17 0		
	I.	Tr. I. First contact	8 0 0	8 0 0	Bad sky now.
		Bisection	8 2 0		
		Inner contact	8 4 0		
	I.	Sh. I. Bisection	8 22 0		
		Just within	8 25 0	8 23 0	
	III.	Sh. E. Inner contact	8 42 0	8 50 0	
		Half off	8 46 0		
		Just off?	8 48 0		
	I.	Tr. E. Bisection	10 17 0	10 20 0	Good definition.
		Last contact	10 20 0		
	I.	Sh. E. First contact	10 41 0	10 42 0	Clouds pass and hide planet.

Phenomena of Saturn's Satellites.

(Power 240.)

January 6, 1885.—Good definition.

Enceladus, S.; very difficult; not up at 8^h, $8^h\ 5^m$, $8^h\ 10^m$, $8^h\ 15^m$, $8^h\ 17^m$, $8^h\ 20^m$ up? $8^h\ 25^m$ past? $8^h\ 30^m$ past.

Tethys, N.; definition poor; not up at $16^h\ 15^m$; up between $16^h\ 16^m$ and $16^h\ 17^m$ probably; $16^h\ 23^m$ past.

January 7.—Very good definition when the clouds clear away; high wind.

Dione, N.; $10^h\ 50^m$, $10^h\ 55^m$ not up; $10^h\ 58^m$ not quite up; $11^h\ 0^m$ on line? $11^h\ 5^m$, on line; $11^h\ 10^m$ past.

January 8.—Very good definition.

Enceladus, N.; reached the telescope too late to see the approach; on the line at $9^h\ 50^m$? $9^h\ 52^m$? $10^h\ 0^m$ past? $10^h\ 2^m$ past.

Tethys, N.; not up at $13^h\ 20^m$, $13^h\ 25^m$; up at $13^h\ 27^m$? $13^h\ 29^m$? $13^h\ 30^m$? past at $13^h\ 33^m$? $13^h\ 35^m$ past.

January 10.—Stormy; bright and clear occasionally

Tethys, N.; $10^h\ 45^m$ not up; $10^h\ 47^m$ up? $10^h\ 49^m$, $10^h\ 50^m$ up? $10^h\ 55^m$ past.

Enceladus, S.; very difficult object; on line at $11^h\ 0^m$? clouds now obscured the planet.

January 11—Windy; snow showers; often clear for a short time.

Tethys, S.; not up at $9^h\ 0^m$, $9^h\ 10^m$, $9^h\ 15^m$, $9^h\ 20^m$, $9^h\ 23^m$, $9^h\ 24^m$, $9^h\ 25^m$ up? $9^h\ 30^m$ $9^h\ 32^m$ up? $9^h\ 35^m$ past? $9^h\ 40^m$ past.

January 12.—Clear at intervals.

Dione, E.; $6^h\ 45^m$, $6^h\ 48^m$ not up? $6^h\ 49^m$, $6^h\ 50^m$ up? $6^h\ 52^m$ up? Clouds now came over.

Tethys, N.; difficult; $8^h\ 0^m$, not yet quite up. Cloud then hid the planet.

January 13.—Bad sky.

Tethys, S.; judged on line between $6^h\ 40^m$ and $6^h\ 50^m$; cloud and snow put an end to observation.

January 14.—Bad sky; could not see *Dione* steadily.

Dione, S.; $7^h\ 0^m$ not up; $7^h\ 5^m$ to $7^h\ 7^m$ up? $7^h\ 9^m$ $7^h\ 10^m$ up? $7^h\ 15^m$ up? $7^h\ 17^m$ past? $7^h\ 20^m$ past.

February 2.—Stormy; good light.

Dione, S.; $10^h\ 45^m$ to $10^h\ 47^m$ not up; $10^h\ 49^m$ to $10^h\ 53^m$ up? $10^h\ 55^m$ certainly not short of line; $10^h\ 57^m$ past? $10^h\ 58^m$ past.

February 3.—Misty; sat. very faint.

Tethys, E.; $12^h\ 15^m$ not up; $12^h\ 30^m$ past.

February 5.—Windy; wet; bright sky occasionally.

Rhea, N.; reached the Observatory too late for the approach; $9^h\ 50^m$ to $9^h\ 52^m$ up? $9^h\ 54^m$ to $9^h\ 55^m$ up; $9^h\ 57^m$ past? $9^h\ 59^m$ past.

Tethys, E.; $9^h\ 45^m$ to $9^h\ 47^m$ on web? $9^h\ 50^m$ past? $9^h\ 52^m$ past.

Enceladus, S.; glimpsed now and then; on web between $11^h\ 45^m$ and $11^h\ 50^m$.

February 7.—Stormy; often very clear.

Enceladus, E.; a very faint point of light suspected on or very near line at $6^h\ 5^m$.

Tethys, E.; $6^h\ 45^m$ to $6^h\ 50^m$ not up; $6^h\ 50^m$ to $6^h\ 57^m$ very nearly on line or quite so; $6^h\ 57^m$ to $7^h\ 0^m$ judged on line; probably past at $7^h\ 5^m$; certainly past at $7^h\ 10^m$.

February 9.—*Dione*, N.; $7^h\ 0^m$ not up; $7^h\ 2^m$ nearly up, $7^h\ 5^m$ on line? $7^h\ 8^m$ on line? $7^h\ 10^m$ past.

February 20.—*Tethys*, E.; $11^h\ 50^m$ not quite up; $12^h\ 0^m$ up? $12^h\ 5^m$ up? $12^h\ 10^m$ past.

Titan is now nearly at E. elongation.

February 22.—*Enceladus*, E.; suspected on line at 8 P.M.

Dione also.

Rhea, $8^h\ 40^m$ $8^h\ 42^m$ not up; $8^h\ 45^m$ $8^h\ 50^m$ up? $9^h\ 0^m$ past? $9^h\ 5^m$ past.

Tethys, just up at $9^h\ 12^m$; not up at $9^h\ 15^m$? $9^h\ 17^m$ to $9^h\ 25^m$ up? $9^h\ 30^m$ past.

February 25.—*Enceladus*, N.; on line at $8^h\ 45^m \pm$.

February 28.—*Dione*, N.; glimpsed occasionally; not on web at $10^h\ 45^m$; on between $10^h\ 50^m$, and $11^h\ 0^m$; past, at $11^h\ 5^m$.

March 7.—Good definition; *Dione*, S.; on web between $7^h\ 0^m$ and $7^h\ 10^m$; $7^h\ 15^m$ past.

March 9.—*Enceladus*, E.; extremely faint; $9^h\ 20^m$ up? $9^h\ 30^m$ past? $9^h\ 35^m$ certainly past. The sky clouded before *Tethys* reached the line.

March 11.—*Tethys*, E.; $8^h\ 50^m$ nearly up; $9^h\ 0^m$ up? $9^h\ 5^m$ past? $9^h\ 10^m$ past.

Dione, N.; $9^h\ 35^m$ nearly on line; $9^h\ 40^m$ and $9^h\ 45^m$ up? $9^h\ 50^m$ past? $10^h\ 0^m$ past.

March 12.—*Rhea*, E., easy; a little past at $10^h\ 20^m$.

Enceladus, N., very difficult; judged on line between $10^h\ 20^m$ and $10^h\ 30^m$.

March 13.—*Tethys*, E., cloudy often; on line about $6^h\ 40^m$.

Dione, E., between $11^h\ 40^m$ and $11^h\ 50^m$; planet low in W.; misty.

March 21.—*Tethys*, N. On the line $7^h\ 15^m$ to $7^h\ 20^m$? $7^h\ 25^m$ past.

Enceladus, S., faint; clearly seen, $8^h\ 10^m$ $8^h\ 15^m$ not up; $8^h\ 20^m$ $8^h\ 25^m$ up? $8^h\ 30^m$ past.

Rhea, E., badly seen; on line $11^h\ 30^m$ $11^h\ 34^m$.

December 15.—Good definition.

Tethys, S.; $9^h\ 42^m$ $9^h\ 47^m$ not up; $9^h\ 50^m$ nearly or quite up; $9^h\ 55^m$ still on line? $10^h\ 0^m$ past.

Lunar Occultations.

January 21, 1885.—B.A.C. 57; fair definition; power, 62; aperture, $9\frac{1}{3}$ inches.

Disappearance, $5^h\ 38^m\ 5^s$, G.M.T.

Reappearance, $6^h\ 48^m\ 33^s$ „

Nautical Almanac times, $5^h\ 39^m$ and $6^h\ 52^m$.

February 20.—38 *Arietis*, $0^h\ 5^m$, escaped occultation; never very near the Moon's limb.

February 22.—*a Tauri*; disappearance, $5^h\ 9^m \pm$; reappearance, $5^h\ 55^m\ 13^s$, G.M.T.

A New Form of Governor for the Driving-Clocks of Equatorials.

By A. Hilger.

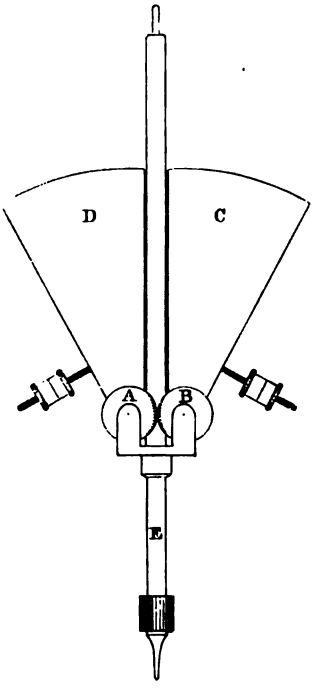
I have the honour of bringing before the Royal Astronomical Society a driving governor which I believe will prove of interest to those who consider uniformity of motion an important matter for an equatorial telescope, and especially to those engaged in the photography of the heavenly bodies.

In former years I have made a great number of Foucault's clocks, with the construction of which many Fellows will be well acquainted, and which twenty years ago were considered—as perhaps they are still, especially in France—the best form of driving-clock for an equatorial. My governor, so far as the fans are concerned, much resembles that of Foucault. A somewhat similar governor, but with three fans, was devised by the late M. Yvon Villarceau; besides these I do not know of any other fan governors, though such may undoubtedly exist.

But there were points in the Foucault governor with which I was by no means satisfied, especially the great complication of pieces and the great amount of friction, which all means error. I do not believe in any form of control which depends upon friction, and finding that, generally speaking, all driving-clocks are so controlled, I have worked out the present design, which is the result of years of experience. I do not think that any governor could have less friction while in action than this particular form, which I claim as my own invention. The friction is entirely confined to the four fine points which carry the two fans D and C. There is no other friction in the governing action whilst these are in motion.

In all forms of governors the clock is liable to go slower either when the fans or governor-balls close, or when the driving weight is reduced. It is not so with this form of clock; an addition of 140 lbs. more or less to the driving-weight will make no appreciable difference in the speed. The speed remains unchanged whether the fans are wide open or nearly closed; I say nearly closed, because, of course, as soon as the fans touch the spindle the control ceases.

The fans are pulled towards the spindle E by chronometer springs in box A and B, which will only allow them to open when a speed of from twenty-five to thirty revolutions a second is attained. The spring is only wound up half a revolution, so that the mean motion of the fans, which does not exceed more than thirty degrees on either side, keeps the spring perfectly free in the air. There is also another very important point in this governor: you will observe that there is no parallelogram motion to keep the fans equally inclined to the centre spindle, and yet that under every variation of position, from vertical to horizontal, the fans always open symmetrically.



When I first tried the governor I found that the rate varied appreciably with the inclination of the fans to the spindle. To overcome this defect I attached small weights to the fans on screws perpendicular to their long axes: and by adjusting the position of these weights on the screws, I found it possible to obtain a quite uniform rate for a very considerable variation in the driving weight, or—what would be the same thing in actual practice—in the friction of the instrument driven.

Note on Mr. Marth's "Intersects." By H. H. Turner, B.A., B.Sc

§ 1. In some recent numbers of the *Monthly Notices* (vol. xlv. pp. 370 and 483), Mr. Marth has described an interesting method of obtaining a graphical representation of the Solar System, each orbit being represented by its trace on a plane which passes through the centre of the Sun and revolves about an axis perpendicular to the ecliptic. The following brief remarks on the general nature of these curves may be of interest:—

§ 2. Let

S be the centre of the Sun, and P any point in the orbit.

i = inclination of orbit to the ecliptic.

ω = angle between line of nodes and major axis of orbit.

r = distance of P from S.

w = " " " " line of nodes.

x = " " " " directrix of orbit.

z = " " " " major axis of orbit.

y = " " " " ecliptic.

p = " " S " directrix of orbit.

Then we have the following relations among these quantities:—

$$\left.\begin{aligned} y &= w \sin i \\ r &= ex \\ r^2 &= (x-p)^2 + z^2 \\ w &= z\cos\omega - (x-p)\sin\omega \end{aligned}\right\} \quad \ldots\ldots\ldots (1)$$

Eliminating w, x, z from these four equations, we get the equation

$$e^2 r^2 \cos^2\omega = e^2 y^2 \operatorname{cosec}^2 i + 2ey(r-ep)\sin\omega \operatorname{cosec} i + (r-ep)^2 \quad \ldots (2)$$

and considering the point in the intersect corresponding to P, as defined by the coordinates r and y, this is the equation to the "intersect."

§ 3. If we write x in place of r in this equation (where x is now the usual Cartesian coordinate), we get the conic

$$x^2(1-e^2\cos^2\omega) + 2e\sin\omega\operatorname{cosec} i \,.\, xy + e^2 y^2 \operatorname{cosec}^2 i,$$
$$-2e^2 p \sin\omega \operatorname{cosec} i \,.\, y - 2ep\,x + e^2 p^2 = o.$$

The second invariant is

$$e^2 \sin^2\omega \operatorname{cosec}^2 i\,(e^2-1)$$

so that the conic is an ellipse, parabola, or hyperbola, as e is $<$, $=$, or $>$ 1 ; *i.e.* is of the same kind as the orbit.

§ 4. The "intersect" may be laid down graphically from this conic in the following manner:—Draw a series of lines parallel to the axis of x, and cutting the axis of y; and with radius equal to the distance on one of these lines between the axis of y and the curve, and the origin as centre, cut this line by a small circular arc. The points of intersection will trace out the "intersect."

The reverse operation will reproduce the conic from the intersect. I have shown in a diagram (Plate 4) some of these conics traced from Mr. Marth's intersects in *Monthly Notices*, vol. xlv. plate 3. Corresponding points in two curves are at the same distance from the axis of x; and one set of curves may be regarded as a kind of distortion of the other.

It is readily seen that

(a) The intersect as given by the equation is symmetrical to the axis of y, since r contains x^2 only. In actual fact, however, we limit the plane to one side of the axis of y.

(b) At points on the axis of x the conic and intersect touch each other, and are generally similar in the neighbourhood of this axis.

(c) Points on the lines $y = \pm x$ for the conic correspond to points on the axis of y for the intersect, and the intersect corresponding to portions of the conic in the quadrants made by these lines remote from the axis of x is imaginary.

In the particular case under consideration, the points of intersection of the conic with the lines $y = \pm x$ are given by the equation

$$[x(e \sin \omega \operatorname{cosec} i + 1) - ep]^2 + e^2 x^2 \cos^2 \omega \cot^2 i = o. \quad . \quad . \quad . \quad (3)$$

which gives imaginary values of x, unless either $\cot i = o$, in which case the orbit is perpendicular to the ecliptic, and the intersect coincides with it, the conic becoming (part of) a straight line parallel to the axis of y; or $\cos \omega = o$, in which case the intersect is part of a conic, and the conic again becomes part of a straight line. The equations of course represent the whole of this conic and this straight line respectively, but we must adduce further considerations to determine which parts of the curves actually correspond to the orbit.

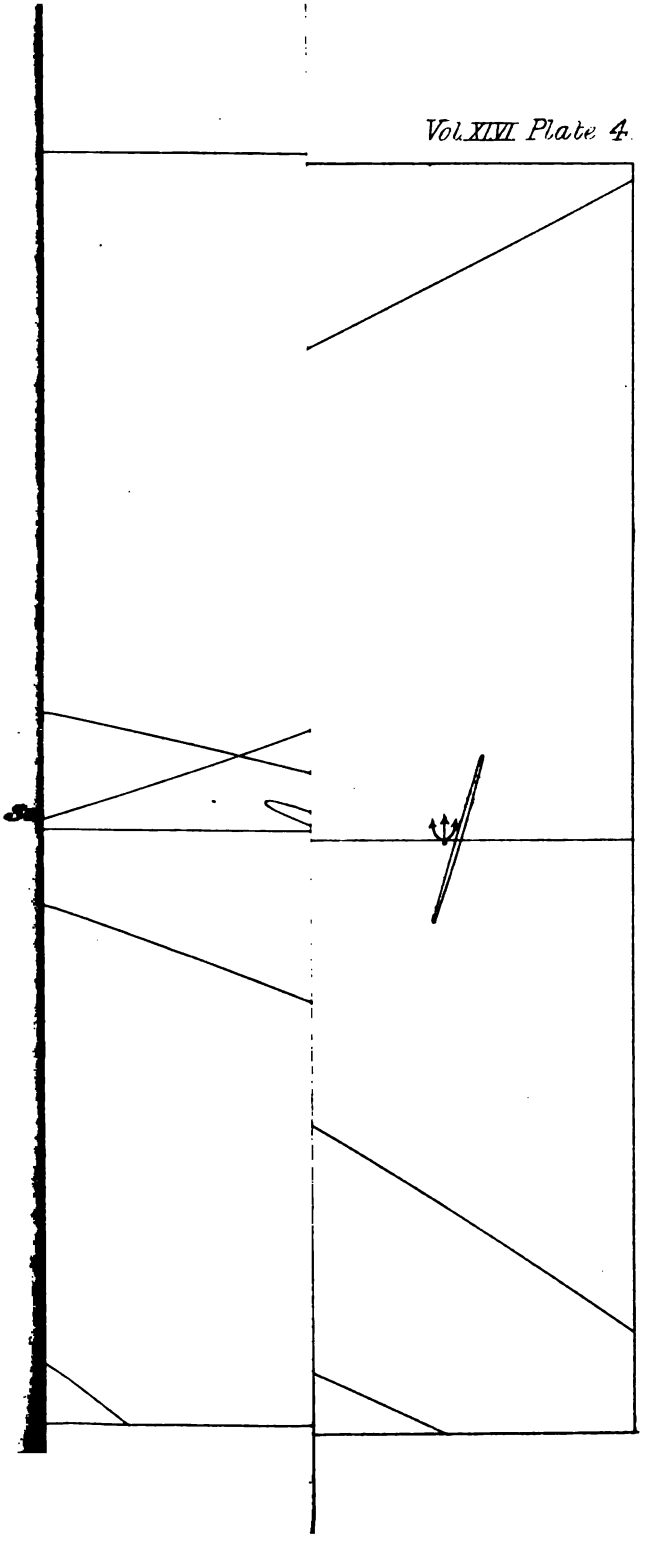
(d) If the conic breaks up into two straight lines, the "intersect" breaks up into two conics with axis of y as major axis and origin as focus. In fact, the equation to the intersect is then of the form

$$(ar + by + c)(a'r + b'y + c') = o,$$

and

$$r = -\frac{by}{a} - \frac{c}{a}$$

evidently represents such a conic.



§ 5. As regards the representation of the Solar system, there are several points in which a diagram of these conics would give much the same information as the diagram of intersects; and, for the construction of such a diagram, in place of the series of co-ordinates for different points tabulated so carefully by Mr. Marth, it would only be necessary to specify the coordinates of the centre, inclination and magnitude of the axes of the conic, to enable any one to reproduce the curves with an ellipsograph. Ambiguity as regards the position of the *major* axis might be removed by giving also the coordinates of the points where the conic cuts the axis of x.

The following expressions for these quantities are readily deducible. If a be the major axis of the orbit, putting

$$e = \sin\phi,\ \sin i \cos\omega = \cot\psi$$

coordinates of centre of conic are

$$x = a \qquad y = -a \sin\phi \sin i \sin\omega :$$

the inclination of the axis to the axis of x is θ, where

$$\tan 2\theta = \frac{\sin\phi \tan\omega \sin 2\psi}{\cos^2\psi \sec^2\omega - \sin^2\phi}$$

The axes are α and β, where

$$\frac{1}{\alpha} \pm \frac{1}{\beta} = \frac{2\sqrt{\cos^2\psi \tan^2\omega + \cos^2(\phi \mp \psi)}}{a \cos\psi \sin 2\phi}$$

§ 6. When the eccentricity of the orbit, and therefore of the corresponding conic, is nearly unity, as in the case of a comet, it may be advisable, owing to the centre occurring outside the limits of the paper employed for plotting the curves, to treat the conic as a parabola, and in this case the position of the focus and directrix will be more useful. The expressions for the co-ordinates of the focus when e is unity are

$$\alpha = \frac{q(1 + \operatorname{cosec}^2 i)}{2(\sin^2\omega + \operatorname{cosec}^2 i)} \text{ and } \beta = \alpha \cdot \frac{\sin\omega}{\sin i}$$

and the equation to the directrix is

$$x + y \sin\omega \sin i = \frac{q}{2} \cos^2 i$$

where q is the semi-latus-rectum of the orbit. The conic can then be drawn by any of the mechanical methods for describing a parabola with given focus and directrix.

§ 7. A diagram of these conics would exhibit facts about perihelion distances perhaps more readily than that of the actual intersects: it need only be remembered that proximity to the Sun is here translated into proximity to the axis of y; and the perihelion and aphelion distances are thus distances from the axis of y to tangents parallel to it.

Facts about "inclination," on the other hand, are not exhibited so obviously. In the neighbourhood of the axis of x the inclination of the radius vector to the axis of x for the conic is nearly equal to that of the corresponding radius in the orbit to the plane of the ecliptic. But a radius in the orbit perpendicular to the ecliptic is represented in the case of the conic by a radius at an angle of 45° with the axis of x; and between these two extremes the inclination suffers a distortion or reduction increasing in value from zero to one half.

Still all comparative properties of two orbits are represented in very much the same way; *e.g.* the agreement or divergence of two orbits of the same comet, computed from different elements, would be exhibited equally well by the diagram of conics; and, since Mr. Marth seems to regard this possibility of recognising at a glance the agreement or divergence of two orbits as one of the chief uses of his diagrams, perhaps the greater facility in tabulation might recommend this rather more artificial but similarly useful method of diagrammatic representation in some cases.

§ 8. I have made a diagram (Plate 4) of the conics corresponding to some of Mr. Marth's intersects, given in the *Monthly Notices*, vol. xlv. Plate 3, by the actual process described in § 4, so that the scale is in a sense the same as in his diagram. The curves for the major planets, being in the neighbourhood of the axis of x, are almost precisely the same on either system.

In the following table are given the calculated values of the coordinates of centre, inclination of axis, and lengths of axes of the conics corresponding to the major planets and a few of the minor planets. I find that these elements may be computed for each planet in less than half an hour:—

Planet.	Coordinates of Centre.		Inclination of Major Axis.	Lengths of Axes.	
			° ′		
Mercury	0·387	−0·005	159 29	0·083	0·038
Venus	0·723	−0·000	5 25	0·042	0·003
Earth	1·000	+0·000	0 0	—	0·000
Mars	1·524	+0·004	18 51	0·009	0·006
Jupiter	5·203	+0·005	25 14	0·292	0·005
Saturn	9·555	+0·009	28 6	0·578	0·358
Uranus	19·218	−0·012	163 49	0·921	0·032
Neptune	30·111	+0·008	74 42	0·988	0·013
(2)	2·763	+0·294	70 20	1·634	0·393
(31)	3·145	−0·276	115 7	1·533	0·302
(84)	2·363	−0·019	166 5	0·566	0·359
(153)	3·951	−0·079	142 18	0·832	0·229
(176)	3·192	−0·001	89 47	1·207	0·525
(190)	3·947	+0·065	32 31	0·762	0·112

Note on the Transit of the Planet Mars and its Satellites across the Sun's disc, which will occur for the Planet Jupiter and its Satellites on April 13, 1886. By A. Marth.

In a "Note on the Transit of the Earth and Moon across the Sun's disc as seen from *Mars* on Nov. 12, 1879," published in vol. xxxix., the statement may be found (on page 487) that the last transit of *Mars* for *Jupiter* had occurred on Aug. 13, 1785, and that the next one would take place, I presumed, in April 1886. Considering the rarity of the event, I have thought it worth the trouble to compute the circumstances of the case properly, in order to gain some distinct notions of the details of the occurrence. But as the data and explanations necessary for verification and more detailed computations would require more space than this note is intended to occupy, I content myself with merely communicating some of the deduced results.

The transit will begin on April 12 at $20^h\ 35^m$ Greenwich Mean Time with the ingress of *Deimos* upon the Sun's disc for the preceding edge of *Jupiter's third* satellite, and will end on April 13 at $18^h\ 17^m$ Greenwich Mean Time, with the egress of *Deimos* for the following edge of the *second* satellite; so that the whole transit will last for *Jupiter's* system 21 hours 42 minutes, during which interval *Phobos* will have made two full revolutions and three-quarters, and *Deimos* nearly three-quarters of a revolution. For *Jupiter* itself the transit will begin on April 13 at $0^h\ 27^m$ with the ingress of *Deimos* at sunset for a point in 16° of jovicentric northern latitude, and in 108° or 175° western longitude, according as the longitudes are reckoned from the Zero-Meridian in the first or second system of longitudes adopted in the ephemeris published in vol. 45, p. 504 ff. The transit will end at $16^h\ 2^m$ with the egress of *Deimos* at sunrise for a point in 14° of jovicentric northern latitude and in 138° or 200° of longitude, so that for *Jupiter* the whole transit of *Mars* and its satellites will last 15 hours 35 minutes, during which interval *Jupiter* itself will have performed one full rotation and a half. With the exception of the small region within 2° of the north pole, the whole surface of *Jupiter* will have come into sunlight, while *Mars* and its satellites are before the disc; for a region extending approximately from longitude 294° to 312° in the first system of longitudes, or from 356° to 19° in the second system, or for a region including the neighbourhood of the great spot, the ingress of *Mars* and of both satellites will take place in the evening of one Jovian day, the middle passage in the middle of the next day, and the egress in the morning of the third Jovian day.

The Greenwich mean times of ingress and egress for the four satellites of *Jupiter* and for the points of first and last touch of the planet with the contact-cones are given below. The angles of position are those of the centre of *Mars*, as seen from *Jupiter*,

and as reckoned from the point which is in the direction of the north pole of *Jupiter's* equator. The jovicentric apparent diameter of the Sun is 352″·57, that of *Mars* 2″·46; the greatest elongation of *Phobos* from the centre of *Mars* is 3″·40; that of *Deimos* 8″·50. At 8h 14m the centres of *Mars* and of the Sun will be jovicentrically at their least apparent distance 40″·30.

Ingress of		*Deimos.*	*Phobos.*	*Mars.* Ext. C.	*Mars.* Int. C.	Angle of Position.
		h m	h m	h m	h m	°
for Sat. III.	April 12	20 36	20 56	20 46	20 52	74·6
Sat. IV.		21 38	21 58	21 54	22 1	75·1
Sat. II.	April 13	0 3	0 20	0 26	0 34	75·8
ϒ prec. l.		0 27	0 39	0 45	0 51	79·6
Sat. I.		still eclipsed		1 8	1 16	76·5
ϒ foll. l.		1 6	1 22	1 24	1 30	78·4

Egress of		*Phobos.*	*Mars.* Int. C.	*Mars.* Ext. C.	*Deimos.*	
for Sat. III.	April 13	10 34	10 25	10 32	10 43	285·3
Sat. IV.		14 0	14 1	14 9	14 29	285·9
ϒ prec. l.		14 53	14 58	15 5	15 22	286·1
ϒ foll. l.		15 33	15 38	15 44	16 2	284·9
Sat. I.		16 43	16 42	16 48	17 1	283·3
Sat. II.		18 6	17 56	18 3	18 17	284·1

The following statements may probably interest some readers.

During the sixty years from 1830 to 1890 there will have taken place seventeen transits of *Mercury* over the Sun's disc for *Jupiter* and its satellites, against seven as seen from the Earth. The dates and the heliocentric longitudes are:—

		°	°			°	°
1833 Dec.	1·8	34·1		1863 Aug.	22·7		212·5
1834 Mar.	1·2	42·3		— Nov.	21·0		219·4
1840 Jan.	15·9		215·6	1869 July	25·5	36·4	
1845 Sept.	19·9	32·2		— Oct.	22·9	44·5	
— Dec.	18·3	40·3		1875 Sept.	8·9		217·8
1851 Nov.	3 8		214·0	1881 May	13·7	34·5	
1852 Feb.	2·0		220·9	— Aug.	11·0	42·7	
1857 July	9·0	30·3		1887 Aug.	27·8		216·1
— Oct.	6·4	38·4					

Venus has during these sixty years crossed the Sun's disc for *Jupiter* eight times:—

		°	°			°	°
1834 Dec.	7·5	67·4		1858 Apr.	16·7	55·7	
1840 Oct.	2·9		235·7	1864 Oct.	5·3		244·1
1846 Aug.	12·1	61·6		1876 June	10·3		239·0
1853 Jan.	30·3		249 2	1882 Apr.	19·7	65·2	

As regards the Earth, the oppositions of *Jupiter* to the Sun or the inferior conjunctions of the Earth recur at intervals of eighty-three years in approximately the same ecliptical longitudes. Nearly one-half of this period of eighty-three years is barren of transits, while during the other half there occur usually eight transits. A cycle of transits ended with that which occurred 1765, Jan. 5·0, in hel. longit. 105°·5. After an interval of forty years without transits the Earth and Moon crossed the Sun's disc for *Jupiter* on the following dates :—

1806 June	25·2	in hel. long. 273°·4	1811 Dec.	23·3	in hel. long. 91°·2
1818	30·1	278·1	1823	28·0	96·1
1830 July	5·0	282·9	1836 Jan.	1·7	100·9
1842	10·0	287·8	1848	6.1	105·1

or at intervals of alternately five and six synodical revolutions. After a barren interval of forty years, a similar cycle of transits will begin with that of 1889 June 24·3 in long. 273°·4, and end with the transit of 1931 Jan. 6. In the course of time changes occur in this arrangement. The transit next preceding that of 1765 Jan. 5 occurred, not in 1759, but 1752 Dec. 31·3, in hel. long. 100°·7 or near the same node, the conjunction of 1759 July 9·6 in long. 287°·6 being merely a close conjunction, the Earth and Moon passing for *Jupiter* just outside the Sun's disc.

So much about the transits of the inferior planets which occur for *Jupiter* and its satellites. Now a few remarks about the occasions when *Jupiter* itself crosses the Sun's disc for the three outer planets.

Since 1690, when *Uranus* was first observed, there have already occurred two transits of *Jupiter* for *Uranus*—at midsummer 1706, and 1789 May 10 in hel. long. 124°·2. The next two transits, I presume, will take place near the other node in the years 1914 and 1997.

As regards *Neptune*, it would demand stricter computations than I have made, and would probably require improved tables, to state decisively whether the conjunctions of the years 1613 and 1779 in the past and those of the years 2022 and 2188 in the future are such close conjunctions as to produce actual transits of *Jupiter* for *Neptune*.

However, the chief question is that concerning transits of *Jupiter*, which may occur for *Saturn*, and, what for observers on the Earth is of greater interest, geocentric occultations of *Saturn* by *Jupiter*. The closest conjunction at which the two planets have been seen since the invention of the telescope was the geocentric conjunction of February 8, 1683, in long. 136° ·7, when the two planets in their retrograde courses passed one another at a distance of 11′. The conjunction was the middle one of a triple conjunction, such as had not occurred since 1425, and as will not occur again till 1940, as I mentioned in an oral communication

made at one of the meetings of the Royal Astronomical Society in 1877 (see the *Astronomical Register*, vol. 15, p. 159). A closer conjunction, both heliocentrically and geocentrically, than that of 1683, was that of July 1623, which was, however, invisible, as it took place not long before the conjunctions of the two planets with the Sun. After twenty-two heliocentric conjunctions since 1623, the next minimum conjunction will occur in May 2080, in which year the two planets will come into opposition to the Sun early in August. The following minima will occur in May 2477, January 2875, &c. An examination of the question, made with the help of Le Verrier's tables in 1878, has satisfied me, that during the next two thousand years as well as during the last two thousand years, or during a full period of four thousand years, no conjunction of the two planets can be found, which takes place so near to the line of nodes of their orbits as to produce a transit of *Jupiter* across the Sun's disc for *Saturn*, or an occultation of *Saturn* by *Jupiter* for observers on Earth.

Ephemeris of the Satellites of Mars, 1886. By A. Marth.

The values of the longitude of the node N and of the inclination J of the orbit of *Deimos*, in reference to the plane of the Earth's equator, employed in the following ephemeris, are

$$N = 49^\circ{\cdot}533, \qquad J = 36^\circ{\cdot}037.$$

The assumed proportion of the mass of the Sun to that of *Mars* is

$$\odot = 3095000.$$

The orbital longitude of *Deimos*, reckoned from the node, is

$$u_2 - 141^\circ{\cdot}43 + 285^\circ{\cdot}1616\,(t - t_0),$$

the epoch t_0 being 1886, March 14·0 Gr.

Phobos is assumed to move in the plane of the orbit of *Deimos*, and its longitude is taken to be

$$u_1 = 56^\circ{\cdot}54 + 1128^\circ{\cdot}8492\,(t - t_0),$$

its value being a little uncertain, as only two position-angles observed during the last opposition are available.

The periods of the sidereal revolutions corresponding to the assumed daily rates of motion are for

Phobos $7^h\ 39^m\ 13^s{\cdot}72$,

and for

Deimos $30^h\ 17^m\ 54^s{\cdot}99$.

a, b major and minor semi-axes of the apparent ellipses described by the satellites.

P position-angle of the minor axes.

U + 180° and B, areocentric longitude and latitude of the Earth referred to the plane of the orbit of *Deimos*, and reckoned from the node.

$u - U$ longitudes of the satellites, reckoned in their orbits from the points which are in superior conjunction with the planet's centre.

	Phobos.				*Deimos.*				
Greenwich Noon. 1886.	a_1	b_1	$u_1 - U$	P	a_2	b_2	$u_2 - U$	U	B
	″	″	°	°	″	″	°	°	°
Feb. 10	17·36	+ 6·68	158·98	22·13	43·43	+ 16·73	245·49	129·54	+ 22·65
11	17·48	6·72	208·09	22·02	43·74	16·83	170·89	129·32	22·62
12	17·60	6·76	257·21	21·91	44·05	16·93	96·30	129·08	22·60
13	17·72	6·80	306·34	21·79	44·35	17·03	21·72	128·82	22·58
14	17·84	6·84	355·49	21 66	44·65	17·13	307·16	128·56	22·55
15	17·96	6·88	44·65	21·53	44·93	17·22	232·60	128·28	22·53
16	18·07	6·92	93·82	21·39	45·21	17·31	158 06	127·99	22·51
17	18·18	6·95	143·00	21·24	45·48	17·40	83·53	127·69	22·48
18	18·28·	6·98	192·19	21·09	45·74	17·48	9·02	127·37	22·46
19	18·38	7·02	241·39	20·93	46·00	17·56	294·51	127·05	22·44
20	18·48	7·05	290·60	20·77	46·24	17·63	220·01	126·71	22·42
21	18·57	7·07	339·81	20·60	46·47	17·70	145·53	126·37	22·39
22	18·66	7·10	29·04	20·42	46·69	17·77	71·05	126·01	22·37
23	18·74	7·12	78·27	20·24	46·89	17·83	356·58	125·64	22·35
24	18·82	7·15	127·51	20·06	47 08	17·88	282·12	125·27	22·32
25	18·89	7·17	176·76	19·87	47·26	17·94	207·67	124·89	22·30
26	18·96	7·19	226·02	19·67	47·44	17·99	133·22	124·50	22·28
27	19·02	7·20	275·28	19·47	47·60	18 03	58·78	124·10	22·26
28	19·08	7·21	324·55	19·27	47·74	18·06	344·35	123·70	22·23
Mar. 1	19·13	+ 7·23	13·82	19·06	47·86	+ 18·09	269·93	123·29	+ 22·21
2	19·17	7·24	63·09	18·85	47·97	18·12	195·51	122·88	22·19
3	19·21	7·24	112·36	18 64	48·06	18·14	121·09	122·46	22·17
4	19·24	7·25	161·64	18·42	48·14	18·15	46·67	122·04	22·15
5	19·26	7·25	210·92	18 20	48·21	18·16	332·26	121·62	22·12
6	19·28	+ 7·26	260·20	17·98	48·25	+ 18·16	257·85	121·19	+ 22·10
7	19·29	7·25	309 48	17·76	48·28	18·15	183·44	120 76	22·08
8	19·30	7·25	358·75	17·54	48·30	18 14	109·03	120·33	22·06
9	19·30	7·24	48·02	17·32	48·30	18·12	34·61	119·91	22·04
10	19·29	7·23	97·29	17·10	48·28	18·10	320·19	119·49	22·02
11	19 28	7·22	146·56	16·88	48·25	18·07	245·77	119·07	22·00
12	19·26	7 21	195·82	16·66	48·20	18·04	171·35	118·65	21·98

Greenwich Noon. 1886.	*Phobos.* a_1	b_1	$u-U$	P	*Deimos.* a_2	b_2	$u-U$	U	B
	″	″	°	°	″	″	°	°	°
Mar. 13	19·24	7·19	245·08	16·44	48·13	18·00	96·92	118·24	21·96
14	19·21	7·18	294·33	16·22	48·05	17·96	22·49	117·84	21·95
15	19·17	7·16	343·57	16·00	47·96	17·91	308·05	117·44	21·93
16	19·12	+ 7.14	32·80	15·79	47·85	+ 17·86	233·60	117·04	+ 21·92
17	19·07	7 11	82·03	15·58	47·72	17·80	159·15	116·65	21·90
18	19·01	7·09	131·25	15·37	47·58	17·74	84·69	116·27	21·89
19	18·95	7·06	180·45	15·17	47·43	17·67	10·22	115·90	21·88
20	18·89	7·03	229·65	14·97	47·27	17·60	295·74	115·53	21·87
21	18·82	7·00	278 84	14·78	47·09	17·53	221·25	115·18	21·86
22	18·74	6·97	328·01	14·59	46·90	17·45	146·76	114·83	21·85
23	18·66	6·94	17·18	14·41	46·70	17·37	72·25	114·50	21·84
24	18·58	6·91	66·33	14·23	46·49	17·29	357·73	114·17	21·84
25	18·49	6·88	115·47	14·06	46·27	17·21	283·20	113·86	21·83
26	18·40	6·84	164 60	13·89	46·04	17·12	208·65	113·56	21·83
27	18·30	6·81	213·71	13·73	45·80	17·03	134·10	113·27	21·83
28	18·20	6·77	262·81	13·57	45·55	16·94	59·53	112·99	21 83
29	18·10	6·73	311·90	13·42	45·29	16·85	344·95	112·73	21·83
30	18·00	6·69	0·98	13·28	45·03	16·75	270 36	112·48	21·84
31	17·89	6·66	50·04	13·15	44·76	16·66	195·75	112·24	21·85
Apr. 1	17·78	+ 6 62	99·08	13·02	44·48	+ 16·56	121·13	112·01	+ 21·86
2	17·67	6·58	148·11	12·90	44·20	16·47	46·50	111·80	21·87
3	17·55	6·54	197·13	12·79	43·91	16·37	331·85	111·60	21·88
4	17·43	6·50	246·13	12·69	43·62	16·27	257·19	111·42	21·90
5	17·31	6·46	295·12	12·59	43 32	16·17	182·51	111·25	21·92
6	17·19	6·42	344·09	12·50	43·02	16·07	107·82	111·09	21·94
7	17·07	6·38	33·05	12·41	42·72	15·97	33·12	110·95	21·96
8	16 95	6·34	81·99	12·34	42·41	15 87	318·40	110·82	21·98
9	16·82	6·30	130 92	12·27	42·10	15·78	243·67	110·70	22·01
10	16·70	6·26	179·83	12·21	41·79	15 68	169·92	110·60	22·03
11	16 57	6·23	228 73	12·16	41·48	15·58	94·16	110·51	22·06
12	16·45	6·19	277·61	12·12	41·17	15·48	19·39	110·44	22·10
13	16·32	6·15	326·48	12·09	40·85	15·39	304·60	110 38	22·31
14	16·20	6·11	15·34	12·06	40·53	15·29	229·79	110·33	22·17
15	16·07	+ 6·07	64·18	12·04	40·22	+ 15·20	154 98	110·30	+ 22·21

These values are to be interpolated for the times for which the positions of the satellites are required, the equation of light having already been taken into account. The position-angles p and distances s are then to be found by means of the formulæ

$$s \sin (p - P) = a \sin (u - U)$$
$$s \cos (p - P) = b \cos (u - U).$$

The satellites move in the direction of *in*creasing position-angles, and will be at their greatest eastern and western elongation (*e* in pos. P + 90° and *w* in pos. P − 90°) about the following Greenwich mean times :—

		Phobos.		*Deimos.*			*Phobos.*		*Deimos.*
1886.		h		h	1886.		h		h
Feb.	10	10·0 *w*	13·8 *e*	17·2 *e*	Mar.	12	9·2 *w*	13·0 *e*	8·3 *w*
	11	12·8 *e*	16·6 *w*	8·3 *w*		13	12·0 *e*	15·8 *w*	14·5 *w*
	12	11·7 *e*	15·6 *w*	14·6 *w*		14	11·0 *e*	14·8 *w*	5·7 *e*
	13	10·7 *e*	14·5 *w*	20·9 *w*		15	9·9 *e*	13·7 *w*	11·9 *e*
	14	13·5 *w*	17·3 *e*	12·0 *e*		16	12·7 *w*	16·5 *e*	18·2 *e*
	15	12·4 *w*	16·3 *e*	18·3 *e*		17	11·6 *w*	15·5 *e*	9·3 *w*
	16	11·4 *w*	15·2 *e*	9·4 *w*		18	10·6 *w*	14·4 *e*	15·6 *w*
	17	10·3 *w*	14·2 *e*	15·7 *w*		19	9·5 *w*	13·4 *e*	6·7 *e*
	18	13·1 *e*	17·0 *w*	6·8 *e*		20	12·3 *e*	16·2 *w*	13·0 *e*
	19	12·1 *e*	15·9 *w*	13·1 *e*		21	11·3 *e*	15·1 *w*	19·2 *e*
	20	11·0 *e*	14·9 *w*	19·3 *e*		22	10·2 *e*	14·1 *w*	10·3 *w*
	21	13·8 *w*	17·6 *e*	10·5 *w*		23	9·2 *e*	13·0 *w*	16·6 *w*
	22	12·8 *w*	16·6 *e*	16·7 *w*		24	12·0 *w*	15·8 *e*	7·8 *e*
	23	11·7 *w*	15·6 *e*	7·8 *e*		25	10·9 *w*	14·8 *e*	14·0 *e*
	24	10·7 *w*	14·5 *e*	14·1 *e*		26	9·9 *w*	13·7 *e*	5·2 *w*
	25	13·5 *e*	17·3 *w*	20·4 *e*		27	8·8 *w*	12·7 *e*	11·4 *w*
	26	12·4 *e*	16·2 *w*	11·5 *w*		28	11·6 *e*	15·4 *w*	17·7 *w*
	27	11·4 *e*	15·2 *w*	17·8 *w*		29	10·6 *e*	14·4 *w*	8·8 *e*
	28	10·3 *e*	14·1 *w*	8·9 *e*		30	9·5 *e*	13·4 *w*	15·1 *e*
Mar.	1	13·1 *w*	16·9 *e*	15·1 *e*		31	8·5 *e*	12·3 *w*	6·2 *w*
	2	12·0 *w*	15·9 *e*	6·3 *w*	Apr.	1	11·3 *w*	15·1 *e*	12·5 *w*
	3	11·0 *w*	14·8 *e*	12·5 *w*		2	10·2 *w*	14·1 *e*	18·8 *w*
	4	13·8 *e*	17·6 *w*	18·8 *w*		3	9·2 *w*	13·0 *e*	9·9 *e*
	5	12·7 *e*	16·6 *w*	9·9 *e*		4	8·2 *w*	12·0 *e*	16·2 *e*
	6	11·7 *e*	15·5 *w*	16·1 *e*		5	11·0 *e*	14·8 *w*	7·4 *w*
	7	10·6 *e*	14·5 *w*	7·3 *w*		6	9·9 *e*	13·7 *w*	13·6 *w*
	8	13·4 *w*	17·2 *e*	13·5 *w*		7	8·9 *e*	12·7 *w*	4·8 *e*
	9	12·4 *w*	16·2 *e*	19·8 *w*		8	7·8 *e*	11·6 *w*	11·1 *e*
	10	11·3 *w*	15·1 *e*	10·9 *e*		9	10·6 *w*	14·4 *e*	17·4 *e*
	11	10·3 *w*	14·1 *e*	17·2 *e*		10	9·6 *w*	13·4 *e*	8·5 *w*

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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EDWIN DUNKIN, F.R.S., President, in the Chair.

Rev. Charles Herbert Griffith, M.A., 1 College Grounds, Brighton;

John Hartnup, Liverpool Observatory, Bidston, Birkenhead;

Duncan Milligan, 21 Spencer Road, Wandsworth Common, S.W.;

Ole Möller, F.R.G.S., 8 Austin Friars, E.C., and 5 Shooter's Hill Road, Blackheath, S.E.;

Captain W. G. Morris, R.E.;

Rev. Charles J. Taylor, M.A., Toppesfield Rectory, Essex; and

Christopher Thwaites, Mem. Inst. C.E., Beccles, Suffolk;

were balloted for, and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE SIXTY-SIXTH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Non-resident	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1884 ...	227	378	1	3	609	49	1	659
Since elected	+5	+24	...	...	...	...	...	...
Deceased	−11	−13	−1	...	...	−1	...	...
Resigned	...	−10	...	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...	...
Removals	+3	−3	...	...	...	...	...	...
December 31, 1885 ...	224	374	0	3	601	48	1	650

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Bankers', Jan. 1, 1885	338	9	2			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds	8	7	11			
				346	17	1
Half-year's dividend on £7,500 Consols	109	4	5			
„ „ £5,700 New 3 per cent. Stock	83	0	2			
„ „ £7,500 Consols	108	15	0			
„ „ £5,700 New 3 per cent. Stock	82	13	0			
Dividends on £500 Metropolitan Stock	14	9	10			
Interest on money on deposit at Bankers'	1	17	0			
				399	19	5
Received on account of Subscriptions:						
Arrears	140	14	0			
263 Annual Contributions for 1885	552	6	0			
1 „ „ 1886	2	2	0			
35 Admission Fees	73	10	0			
29 First Contributions	43	1	0			
				811	13	0
8 Composition Fees				168	0	0
Sales of Publications:						
At Williams and Norgate's, 1884	38	10	8			
At Society's Rooms, 1885	26	18	0			
				65	8	8
Due to Assistant Secretary on Petty Cash Account, Dec. 31, 1885				13	3	7
				£1,805	1	9

Astronomical Society, from Dec. 31, 1884, to Dec. 31, 1885.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	225	0	0			
,, ,, for assistance in editing Society's Publications ...	50	0	0			
				275	0	0
Income Tax and House Duty				10	10	0
Fire Insurance				7	16	6
Printing	682	9	0			
Engraving and Lithography	30	7	4			
Computation of Ephemerides in *Monthly Notices* ...	50	0	0			
				762	16	4
Turnor and Horrox Funds: purchase of Books for Library	11	0	6			
Binding Books in Library	24	0	11			
Library Catalogue	55	5	0			
				90	6	5
House Expenses	33	2	4			
Wages	28	14	0			
Postage, &c.	62	0	6			
Carriage of Parcels, &c.	2	10	1			
Stationery and Office Expenses	2	7	8			
Expenses of Meetings	20	0	0			
Coals and Gas	52	3	11			
Repair of Gas Meter	5	6	0			
Care of Fire-extinguishing Apparatus	5	6	8			
Sundry Fittings and Repairs	7	17	5			
Sundries	3	3	6			
				222	12	1
Lee Fund				5	0	0
Mrs. Jackson Gwilt's Annuity				8	19	0
Bankers' Commissions on Cheques				0	2	4
Balance at Bankers', Dec. 31, 1885	395	2	7			
,, in hand of Assistant Secretary on account of Turnor and Horrox Fund	22	7	5			
				417	10	0
Paid Balance due to Assistant Secretary, Jan. 1, 1885, on Petty Cash account				4	9	1
				1,805	1	9

Audited and found correct, Jan. 6, 1886.

RICHARD INWARDS.
GEO. S. CRISWICK.
THOS. BUCKNEY.

Assets and Present Property of the Society, Jan. 1, 1886.

	£	s.	d.	£	s.	d.
Balance at Bankers', including an amount of £36 5*s.* 3*d.*, being the accumulated interest of the Lee Fund, Dec. 31, 1885	395	2	7			
„ in hand of Assistant Secretary on account of Turnor and Horrox Funds	22	7	5			
	417	10	0			
Less due to Assistant Secretary on Petty Cash account	13	3	7			
				404	6	5
Due on account of Subscriptions:						
3 Contributions of 4 years' standing ...	25	4	0			
20 „ 3 „ ...	126	0	0			
24 „ 2 „ ...	100	16	0			
58 „ 1 „ ...	118	18	0			
1 Admission Fee and First Contribution ...	3	3	0			
				374	1	0
Due from Messrs. Williams and Norgate for sales of Publications during 1885				29	15	7

£7,500 Consols, including the Lee Fund, the Turnor Fund, and the Horrox Memorial Fund.

£5,700 New 3 per cent. Stock, including Mrs. Jackson Gwilt's gift (£300).

£500 Metropolitan Board of Works Stock.

Astronomical and other Manuscripts, Books, Prints, Instruments, and Furniture.

Unsold Publications of the Society.

Report of the Auditors.

We, being the duly appointed Auditors, beg to lay before this Annual General Meeting of the Royal Astronomical Society the following Report:—

We have examined the Treasurer's account, and have found and certified the same to be correct. The receipts and expenditure for the past year are as stated in the Treasurer's account. The cash in hand on December 31, 1885, including the balance at the bankers', amounted to 417*l.* 10*s.* 0*d.*

The funded property is the same as at the end of last year.

The books, instruments, and other effects have been examined and found to be in a satisfactory condition so far as their safe keeping is concerned. A 6-inch Grubb telescope, without stand, has been received from the Transit of Venus Committee, to replace the $4\frac{6}{10}$ inch telescope, No. 29(3), which was lent to the Committee in 1882, and lost in the *City of Brussels*.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) Richard Inwards.
Geo. S. Criswick.
Thomas Buckney.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXIX.	411	...
I. Part 2	43	...	XXX.	163	...
II. Part 1	53	...	XXXI.	145	1
II. Part 2	21	...	XXXII.	158	...
III. Part 1	66	1	XXXIII.	166	1
III. Part 2	85	1	XXXIV.	166	6
IV. Part 1	80	3	XXXV.	110	6
IV. Part 2	92	3	XXXVI.	199	10
V.	107	4	XXXVII. Part 1	340	4
VI.	126	3	XXXVII. Part 2	288	4
VII.	146	3	XXXVIII.	277	1
VIII.	128	3	XXXIX. Part 1	249	4
IX.	135	3	XXXIX. Part 2	254	4
X.	148	...	XL.	273	...
XI.	155	...	XLI.	421	...
XII.	162	...	XLII.	240	4
XIII.	165	1	XLIII.	248	1
XIV.	371	3	XLIV.	227	1
XV.	141	...	XLV.	264	2
XVI.	168	1	XLVI.	259	2
XVII.	149	2	XLVII. Part 1	3	...
XVIII.	148	...	XLVII. Part 2	21	...
XIX.	155	...	XLVII. Part 3	2	...
XX.	145	..	XLVII. Part 4	13	...
XXI. Part 1	314	...	XLVII. Part 5	13	...
XXI. Part 2	99	...	XLVII. Part 6	13	...
XXI. 1 & 2 (together)	63	1	XLVII.	254	7
XXII.	157	...	XLVIII. Part 1	347	6
XXIII.	152	...	XLVIII. Part 2	411	7
XXIV.	159	1	Index to *Memoirs*	645	1
XXV.	170	...			
XXVI.	174	2			
XXVII.	424	1			
XXVIII.	386	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	70	...	XXV.	7	...
II.	71	...	XXVI.	9	...
III.	...	...	XXVII.	3	...
IV.	...	...	XXVIII.	71	1
V.	...	...	XXIX.	52	...
VI.	38	...	XXX.	63	2
VII.	2	...	XXXI.	96	...
VIII.	139	2	XXXII.	117	5
IX.	22	3	XXXIII.	100	2
X.	175	1	XXXIV.	79	2
XI.	185	1	XXXV.	61	1
XII.	11	2	XXXVI.	32	1
XIII.	158	3	XXXVII.	38	3
XIV.	109	3	XXXVIII.	102	2
XV.	128	2	XXXIX.	100	1
XVI.	107	2	XL.	113	3
XVII.	136	1	XLI.	114	3
XVIII.	166	...	XLII.	122	5
XIX.	56	...	XLIII.	126	3
XX.	34	...	XLIV.	130	8
XXI.	17	...	XLV.	137	5
XXII.	32	...	Index to *Monthly Notices*	568	1
XXIII.	19	...			
XXIV.	23	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLV. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.

No. 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection:—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length; with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

No. 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantagraph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 70. Portable Equatorial stand (lost in the "City of Brussels").
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watchcase, by Professor Chevallier.
„ 92. 2-foot protractor, with two moveable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2 feet 6 inch navy telescope with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatoreal sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Small brass astrolabe.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 116. A pair of 18-inch globes.
„ 117, „ 118. Two old sun dials.

No. 119. Specimens of rulings on speculum metal, by Prof. W. A. Rogers, presented by H. J. Chaney, Esq.
„ 120. A 6-prism spectroscope, by Browning, presented by J. D. Perrins, Esq.
„ 121. Improved maximum and minimum thermometer, presented by E. J. Spitta, Esq.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel, presented by R. J. Ryle, Esq.
„ 123. A 6-inch refracting telescope, by Grubb, with 6 eyepieces, solar diagonal, 2 dark wedges, &c. (To replace telescope 29 (3), lost.)

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 22. The *Matthew* equatoreal, to Mr. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 29. (3) Three micrometers, to Mr. E. Ristori.
„ 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. H. Sadler.
„ 31. (5) $2\frac{3}{4}$-inch telescope and stand, to Mr. E. Ristori.
„ 34. (8) Transit instrument, to Prof. C. Pritchard.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„ 74. Registering spectroscope, to Mr. E. B. Knobel.
„ 120. 6-prism spectroscope, to Lieut.-Col. G. L. Tupman.
„ 123. 6-inch telescope, to Lord McLaren.

The Gold Medal.

The Council have awarded the Society's Gold Medal jointly to Prof. E. C. Pickering and Prof. Charles Pritchard for their photometric researches. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

Vol. XLVIII., Part 2, of the *Memoirs* has been published during the year. It contains the following papers:—

Fourth Catalogue of Micrometrical Measures of Double Stars, made at the Temple Observatory, Rugby. By G. M. Seabroke.

On the Relative Proper Motions of 40 Stars in the *Pleiades*, determined from Micrometric and Meridional Observations. By Prof. C. Pritchard.

Observations of *Mars* at the Opposition of 1884. By E. B. Knobel.

On the Corrections required by Hansen's "Tables de la Lune." By E. Neison.

Sur une inégalité lunaire à longue période. By M. C. Gogou.

Library Catalogue.

A Catalogue of the Library has been prepared by the Assistant-Secretary, which is now in the press, and will shortly be in the hands of Fellows.

Lunar Computations.

The Royal Society have granted to the Secretary, as representing the Council, the sum of 320*l.* from the Government Grant Fund for the purpose of comparing Greenwich Lunar Observations 1847 to 1861 with Hansen's "Tables de la Lune." The computations are being made under the superintendence of Mr. Hind, and they will probably be completed before the next Annual Report.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year:—

Fellows:—Admiral H. W. Bayfield.
Rev. R. H. Blair.
Sir F. J. O. Evans.
F. T. Hall.
Major-General J. C. Hannyngton.
John Hartnup.
E. W. Jones.
William Ladd.
James Lawson.
James McDowell.
Nicholas Martindale.
Colonel Charles Ratcliff.
Rev. William Read.
The Earl of Shaftesbury.
Joseph Sidebotham.
Rev. T. A. Southwood.
Marcus Warburg.
John Watson.
Rev. T. W. Webb.
William Wray.
Colonel William Yolland.

Associate:—Thomas Clausen.

Admiral Henry Wolsey Bayfield was born in the year 1795. At the early age of eleven he entered the Royal Navy on board the *Beagle* sloop as a first-class volunteer. After having been employed on several naval stations between 1806 and 1813, he was in 1814 attached to the squadron stationed in Canada during the latter part of the second American war. He obtained his first commission on March 20, 1815, and soon after he became permanently employed on the survey in that colony, in which he became distinguished as a most valuable scientific officer. From September, 1816, to the date of his retirement from active service in 1856, on his promotion to the rank of rear-admiral, he was continuously engaged on the survey of the coasts and rivers of Canada and other British possessions in North America,

including the lakes Ontario, Huron, and Erie, the river St. Lawrence, and the coast of Labrador. Captain Bayfield, in times of leisure from his surveying duties, was accustomed to observe occultations of stars by the Moon, the phenomena of *Jupiter's* satellites, &c. Some of these observations are recorded in the *Monthly Notices*. At Quebec he observed the transit of *Mercury* of May 5, 1832, with one of Jones's 3½-foot achromatic refractors. In 1848 he communicated to the Society an excellent series of observed occultations of stars by the Moon and phenomena of *Jupiter's* satellites made at his residence at Charlottetown, Prince Edward Island, together with the resulting determinations of the longitude of his residence, from which he deduced the longitude of the Observatory Bastion at Quebec. The reductions appear to have been made with some care, after applying to the tabular places of the Moon corrections furnished by the Astronomer Royal.

Admiral Bayfield attained the rank of Post-Captain in 1834, Rear-Admiral in 1856, and Admiral in 1867. His death took place at Charlottetown on February 10, 1885, in the ninetieth year of his age. He was at the time of his decease the senior Fellow of the Society, and the last of the "non-resident" Fellows, having been elected on May 11, 1827.

Captain Sir Frederick J. O. Evans, R.N., K.C.B., F.R.S., entered the Royal Navy in the year 1828, and served in H.M. ships *Rose* and *Winchester*, on the North American station, until 1833, when he was transferred to H.M. surveying-vessel *Thunder*, Commander Richard Owen, and was employed until 1836 in surveying operations in various parts of the West Indies.

It was in this ship, and under the guidance of her able captain, that he imbibed those scientific tastes which formed his character later in life, and laid the foundation of a career of usefulness, uninterrupted to its close, and which has perhaps rarely found a parallel in the naval profession.

Mr. Evans subsequently served in the *Caledonia*, the flagship in the Mediterranean, the *Asia*, the *Rapid*, the *Rolla*, the *Dido*, and *Wolverene*, of which two latter ships he was acting master. He was confirmed in that rank in 1841, and was then appointed to H.M.S. *Fly*, Captain F. P. Blackwood, fitting for special exploring and surveying service in Australia and New Guinea, where he was continuously employed until 1846. He took a very leading part in the examination of the Coral Sea, the Barrier Reefs of Australia, Torres Strait, and the neighbouring shores of New Guinea, regions then comparativeiy unknown. After a short period of surveying service on the home coasts, Evans was appointed to the *Acheron*, under the late Admiral Stokes, and was engaged until 1851 in exploring and surveying the coasts of the then young colony of New Zealand; in both these important enterprises he took a very conspicuous part, and gained for himself the reputation of a skilful and scientific surveying officer, second to none in the profession.

During the Russian War Evans was employed in the Baltic on special reconnoitring service, and was attached to various ships of the fleet, taking an active part in the operations against Bomarsund and among the Aland Isles, for which he was mentioned in gazetted despatches.

It may be truly said that for many years of his life Evans was a zealous contributor to magnetic science. He had already begun to make observations of the three magnetic elements whilst employed on hydrographic work in H.M. ships *Fly* and *Acheron* in the Australian Colonies and New Zealand, between the years 1842 and 1851; but it was not until 1855, when he became Superintendent of the Compass Department of the Royal Navy that he was able to devote himself entirely to the magnetism of iron ships, a subject which was then growing yearly in importance, from the increasing amount of iron used in fitting as well as construction even before iron plating had brought about an actual crisis.

Sagaciously foreseeing the important part the science of magnetism was destined to play in the Navy, then being revolutionised by the change from wood to iron, he devoted his whole energies to the study of the subject until he had made himself completely master of it.

In 1865 Capt. Evans was appointed Chief Assistant to the Hydrographer, retaining his position as head of the magnetic department; this post he continued to hold until the early part of 1874, when a vacancy occurring in the Hydrographership of the Admiralty he was selected to fill it, and continued to do so with equal ability and conscientiousness until within a little more than a year of his death.

From the time of his first appointment in 1855 as Chief of the Admiralty Compass Department until his death Capt. Evans (in happy co-operation during a great part of the time with that great mathematical genius Archibald Smith) devoted himself heart and soul to the solution of what was really a question of life and death to the British Navy, and indeed to seafaring people all over the world. The question was whether it was possible so to deal with the disturbing element of iron, then entering largely into the construction of ships of all kinds, as to prevent the time-honoured compass from becoming a useless toy, or even a misleading guide. Now that the difficulty has been grappled with and conquered, we have half learned to forget the magnitude of the peril. But for the scientific and practical progress due to the labours of Capt. Evans and Archibald Smith we might almost with advantage have thrown all our compasses overboard. The attraction due partly to the inherent and partly to the induced magnetism of iron ships, and especially of plated ships, was so violent as to induce in some vessels, in certain positions, errors of two, three, or four points of compass indication. Something had been done to explain the causes of the mischief and to suggest palliatives. Famous old Flinders, at the

beginning of the century, had spelt out the mystery so far as it was disclosed by the wooden ships of his time, but he had to deal with comparatively minute errors due to induction alone, and was never brought face to face with the stupendous difficulty which iron shipbuilding and iron ship-plating afterwards created. Sir George Airy had done good and sound work in the earlier days of iron, but much more was needed to overcome the serious trouble which the newer types of mercantile and still more of naval vessels threatened to bring upon us.

It was at this critical epoch that Capt. Evans and Archibald Smith began to work together. Years of experimental labour and mathematical research went to the production of the "Admiralty Manual on Deviations of the Compass"—a book perhaps as perfect in its kind as a book could be. It is hard to do justice to the elegance of the mathematical handling, and, above all, to the happiness of the graphic methods which are found in the Manual, without seeming to indulge in extravagant laudation.

The various steps of Evans's work may thus be stated:—

In 1858 a Chart of Curves of Equal Magnetic Declination, compiled by him for that epoch, was published by the Admiralty. This chart appeared most opportunely, for, with compass errors growing in amount and complexity, the mariner was by means of it enabled to ascertain in any part of the navigable world how far his compass deviated from the magnetic north.

In 1859 he read a paper on the magnetism of iron ships at the Royal United Service Institution. This was a valuable *résumé* of all that had been hitherto done in order to obtain a knowledge of the magnetism of iron ships and the treatment of their compasses. He also communicated some results of Archibald Smith's method of analysis as applied to the errors of the compass found in H.M. ships.

Evans's next paper consisted of a Report to the Hydrographer of the Admiralty on Compass Deviations in the Royal Navy. It treated of the magnetic character of the various iron ships in the Navy, and also of the *Great Eastern* steamship. The results of this paper were (1) to show the best direction for building an iron ship; (2) the best position for placing her compass; (3) the various sources of error affecting a compass under favourable conditions. This report was communicated to the Royal Society, and published in their "Transactions" in 1860.

In 1861 he read a paper of similar import before the Institute of Naval Architects.

Reference has already been made to his work on the *Great Eastern*, and an important result of it was the experimental investigation which he was led to make as to the cause of the abnormal errors of the compasses in that vessel, proceeding from the application of Airy's system of magnet and soft-iron correctors when long single-compass needles are used.

With Evans principally as an experimentalist and Archibald Smith as the mathematician, a valuable paper on the proper

length and arrangement of the needles on a compass card, together with exact information as to the proper arrangement of magnet and soft-iron correctors with respect to it, was presented to the Royal Society in 1861, being the result of the joint work of those ardent investigators into the compass question in iron ships.

Commencing with this latter paper, we find Evans and Smith, as we have said above, generally working together, and under their joint editorship there appeared in 1862 the first edition of the "Admiralty Manual for Deviations of the Compass." The introduction, however, of armour-plated ships soon rendered a new edition necessary, and in 1863 it was published. This work was again revised in 1869, and became the text-book of the world on the important question of the deviations of the compass in iron ships of whatever form, being translated into all the principal European languages.

In 1865 Evans and Smith produced another important paper on the "Magnetic Character of the Armour-plated Ships of the Royal Navy," which was published in the "Phil. Trans. Roy. Soc."

It was only natural that a joint editor of the "Admiralty Manual for Deviations of the Compass," who knew the difficulties of that work for his fellow-seamen, should wish to present the subject, on which he had worked so long, in an elementary form more suitable to their every-day requirements. Evans therefore, in 1870, published his "Elementary Manual for Deviations of the Compass," a work which has been very well received by the nautical world, and has been translated into various European languages.

With the exception of some papers read at certain meetings of the British Association, and two lectures read at the Royal United Service Institution in 1865 and 1872, Evans subsequently relaxed his personal investigations into the magnetism of iron ships, and turned more to terrestrial magnetism.

Thus, in 1872 he contributed a paper to the Royal Society, on the magnetic declination in the British Islands, and compiled the magnetical instructions for the voyage of H.M.S. *Challenger*, being again assisted in this, and for the last time, by his old fellow-labourer, Archibald Smith.

Lastly, in 1878, Evans read an able and instructive lecture, on the magnetism of the earth, before the Geographical Society, showing the distribution and direction of the earth's magnetic force and the changes in its elements as then known.

Captain Evans was elected a Fellow of the Royal Society in 1862. He sat for many years on its Council, and was more than once a Vice-President. He was also a Fellow of the Royal Astronomical and Geographical Societies; he served for many years as member of the Meteorological Committee of the Royal Society, and on the change in the constitution of that body became a member of its Council.

In recognition of his public services the Companionship of the Bath was conferred upon him in 1873, and in 1881 he was advanced to Knight-Commandership of the same order.

Sir Frederick Evans's last public service after his retirement from the Admiralty in 1884 was as the British Delegate at the Congress of Washington for the establishment of a prime meridian and questions kindred to it.

He died on December 20, 1885, in his 71st year.

He was elected a Fellow of this Society on December 12, 1856.

MAJOR-GENERAL JOHN CAULFIELD HANNYNGTON, Fellow of the Institute of Actuaries, was born in Dungannon, Co. Tyrone, on March 7, 1807. He entered the army as a cadet in 1825, and served in the 24th Regiment of Native Infantry until, on the suppression of the Colekan insurrection, he received a political appointment, and was placed in charge of the Mànbhoom Division on the southern frontier, where he remained until, in 1842, he was selected to fill the highest judicial position on the frontier, that of Judicial Commissioner.

On his promotion to the rank of Lieut.-Colonel, in 1856, he returned to regimental duty, in accordance with the regulations of the Service, and took command of the 63rd B.N.I. He was with his regiment at Berhampore at the time of the Mutiny in 1857, and was for some time in command of the station. The 63rd did not mutiny, but were disarmed.

The reputation which Colonel Hannyngton had acquired led very shortly to his transfer to the Military Finance Department, and finally to his appointment as Military Auditor-General, in which office he remained until the close of his active military career in 1861, when he retired on his pension.

Throughout nearly the whole of his service General Hannyngton sedulously watched over the affairs of the Bengal Military and Orphan Funds, and placed his knowledge, his skill, and his labour gratuitously at the disposal of the directors of those splendid institutions. He was, in fact, their most able consulting actuary. True it is that to his sympathetic nature it was always a labour of love to work for the widow and orphan; but only those who know the responsibilities, anxieties, and arduous nature of the actuarial duties connected with institutions of the magnitude of the Bengal Military and Orphan Funds can duly appreciate the self-sacrificing devotion of one who voluntarily and gratuitously undertook such onerous duties in addition to his daily official work in the administration of justice in a large province.

After his retirement the services of General Hannyngton, as a skilful actuary, were on several occasions called into requisition by the Secretary of State for India with regard to the affairs of the Staff Corps and on other matters. To him are due also the whole of the calculations and arrangements under which the Government took over the Annuity and Civil Funds of the

Civil Services of Bengal, Madras, and Bombay, involving questions amounting to millions of pounds sterling between the Government and the members of those distinguished Services, their widows and children. The last of these laborious undertakings, for which, from his knowledge of India and the circumstances of the cases, he was so pre-eminently qualified, had been but very recently completed when he died.

In 1872 he was appointed Assistant Secretary in the Finance Department of the India Office, and remained in that appointment to the end of his long life of zealous, indefatigable, eminently useful, and well-nigh unique service. He may most truly be said to have died in harness.

General Hannyngton's scholarly and scientific attainments were great and varied. To unusual mathematical acquirements as applied to astronomy and navigation were united actuarial abilities of a very high order. He was a good scholar in Oriental languages, more especially in Bengalee. By practice during a long series of years in the performance of his judicial duties he had made himself an expert shorthand writer. The value of Thoman's arithmometer was very early recognised by him, and he was the first to avail himself of it in the calculation of life contingencies. To his intelligence and mathematical power is due the invention of a very ingenious and useful slide-rule. His best known and largest work is a table of Haversines, natural and logarithmic, used in computing distances for the "Nautical Almanac." It was printed by the Admiralty, and is a fitting and enduring monument of his patient and persevering industry.

General Hannyngton was a truly pious, simple-minded, Christian gentleman, trusted, respected, and beloved by all who knew him.

He was elected a Fellow of this Society, 1875, March 12.

JOHN HARTNUP was born at Hurst Green, in Sussex, on January 7, 1806. His first astronomical work of importance was performed at Mr., afterwards Lord, Wrottesley's private observatory at Blackheath, where he was employed as assistant. The part taken by Mr. Hartnup in the observations of the Wrottesley Catalogue of Stars is referred to in the Society's *Monthly Notices*, No. 1, Vol. iv. He was subsequently engaged as a supernumerary at the Royal Observatory, Greenwich, and afterwards became Assistant Secretary to the Royal Astronomical Society. The results of a series of observations made by Mr. Hartnup with a sextant and pocket chronometer for determining the latitude and longitude of the Society's apartments at Somerset House are given in the *Monthly Notices*, No. 2, Vol. vi. In November, 1843, Mr. Hartnup was appointed Director of the Liverpool Observatory. A few words as to the objects of this establishment may perhaps not be out of place.

Between the years 1834 and 1838 urgent requests were

frequently made by officers in the Royal Navy and in the Mercantile Marine, astronomers, and various scientific men, for the establishment of a Nautical Observatory at Liverpool. In 1837 a memorial was presented to the Corporation by the British Association for the Advancement of Science. The memorial drew attention to the fact that no one was responsible for giving correct time to the port; that chronometer-makers could not be trusted to make the necessary astronomical observations themselves, as they had been known to differ from each other as much as two minutes in the Greenwich mean time, and that such errors must be dangerous to vessels leaving the port. A committee of the Town Council appointed to take the matter into consideration reported that the means for giving accurate time to the port did not exist, and that chronometers were sent to sea with various sources of error. The chief objects, then, of the establishment of an observatory in Liverpool were the communication of accurate time to the port and the rating of chronometers.

The great differences frequently found to exist between the sea and shore rates of chronometers was a subject which appeared enveloped in mystery. Mr. Hartnup found change of temperature to be the chief cause of these changes of rate. No. 8, vol. ix., of the Society's *Monthly Notices* contains a paper by Mr. Hartnup on an improved form of compensation balance. This balance is practically perfect in its action, as chronometers to which it is applied maintain very nearly the same rate in extremes of heat and cold and in the middle temperature. It is, however, not nearly so strong as the ordinary form, is much more difficult to make and also to adjust, and is liable to be injured by unskilful hands. Although the architect availed himself of the advice of the best authorities of that day on the construction of the building, no provision was at first made for controlling the temperature in the chronometer-room at the Liverpool Observatory. Limited arrangements for this purpose were afterwards made at Mr. Hartnup's request. The Report for 1854 of the British Association for the Advancement of Science contains a paper by Mr. Hartnup on the variation in the rates of chronometers, and tables are given showing the change in the daily rate of each of one hundred chronometers caused by changing the temperature from 40 to 60, from 60 to 80, and from 50 to 80 degrees Fahrenheit. In consequence of Mr. Hartnup's reports on the importance of testing chronometers before they are used at sea the Mersey Docks and Harbour Board extended and improved the arrangements for testing these instruments, and soon after the removal of the Observatory to Bidston, permission was given by the Board to establish a system of testing chronometers in the two extremes and middle temperature to which ships are generally exposed at sea. A careful examination of the results obtained from the tests of upwards of a thousand chronometers in the three definite temperatures of 55, 70, and 85 degrees Fahrenheit showed:—

1. That there was a definite temperature peculiar to each chronometer, in which it went faster than in any other temperature.
2. As the number of degrees above or below the temperature of maximum gaining rate increased, the chronometer lost in a rapidly increasing ratio.
3. Rates calculated on the assumption that the rate changes directly as the square of the number of degrees from the temperature of maximum gaining rate agreed closely with rates obtained from observation.

In his Report for 1872 to the Marine Committee of the Mersey Docks and Harbour Board, Mr. Hartnup gives a formula for calculating the correction due to thermal error, for any temperature of a chronometer whose rate has been determined by observation in the three definite temperatures of 55, 70, and 85 degrees Fahrenheit. An example showing the advantage of applying such corrections to the rates of two chronometers during a voyage from Liverpool to Calcutta is given in No. 2, vol. xxxv., of the Society's *Monthly Notices*. Vol. iii. of the "Dun Echt Observatory Publications," recently issued by the Earl of Crawford and Balcarres, contains a detailed account of the determination of the temperature corrections of the fifty chronometers employed on his expedition to Mauritius for the observation of the Transit of Venus in 1874. These chronometers were tested at the Liverpool Observatory both before and after the expedition, and Mr. Hartnup's formula was used in the calculation of the corrections for thermal error. In 1877 the Directors of the Pacific Steam Navigation Company ordered the chronometers belonging to their ships to be sent to the Liverpool Observatory to be rated. The notices as to the work at the Liverpool Observatory contained in the annual Reports of the Council of the Society show the careful attention given by Mr. Hartnup to the performance of these chronometers and the accuracy with which Greenwich time can be carried on at sea with chronometers of average quality, when their thermal errors are determined at an observatory provided with efficient apparatus for the purpose, and the corrections due to change of temperature are applied to the rates.

The Liverpool Observatory is provided with an equatoreal of great firmness and steadiness, and Mr. Hartnup's early reports show his ability in the use of this instrument. The results of observations of comets and of several of the minor planets were communicated to the Society, and published in the *Monthly Notices*. The chronometric work, however, gradually became heavier. A large number of chronometers were deposited at the Observatory for the purpose of being rated, and Mr. Hartnup considered the investigation of their performance under varying conditions the most important work to which he could devote his energies and the means at his disposal.

An excellent method of controlling clocks by electric currents was first adopted at the Liverpool Observatory. A paper by Mr. Hartnup on this subject is published in the Report for 1857 of the British Association for the Advancement of Science.

Mr. Hartnup resigned the directorship of the Liverpool Observatory in May, 1885. His health had been failing for some time, and on his retirement he took up his residence in London, chiefly with the view of obtaining medical advice. He died suddenly in London on October 20, 1885.

Enough has been said to show the great amount of labour bestowed by Mr. Hartnup on the subject of marine chronometry. The highest authorities have spoken in strong terms of the utility of the work done at the Liverpool Observatory in testing chronometers for the mercantile marine. Sir G. B. Airy, K.C.B., when Astronomer Royal, repeatedly alluded to the importance of this work. Mr. Hartnup was elected a Fellow of the Royal Astronomical Society on February 14, 1845.

William Ladd was born at Deal in 1815, whence he came to London at the age of 14. Mr. Ladd was well known in scientific and commercial circles for his efforts in aiding research, for during the decade extending from 1860 to 1870 he took a very prominent part in introducing electricity into practical utility. Nor was his interest in this line confined merely to any particular branch of the science, for we find him at one time in correspondence with Prof. Reis, who may be said to have made the earliest efforts towards recording the sound of the human voice transmitted over long distances. A letter is still extant in which Prof. Reis explains to Mr. Ladd his views upon this question, and the partial success that attended his efforts. Mr. Ladd was well known as the constructor of some of the largest induction coils and electrical apparatus, manufactured under his supervision at his premises in Beak Street, Regent Street.

In 1867 Mr. Ladd brought forward a dynamo machine, which in many respects showed a marked improvement on the previous dynamos of Siemens, Varley, and Wilde, and whereby many of the then existing difficulties in the way of constructing dynamos for practical and commercial use were removed. Somewhat later, in the year 1878, Mr. Ladd was instrumental in introducing into this country the Wallace-Farmer system of electric lighting from America, where it had met with considerable success. The dynamos and arc lamps employed on this system underwent considerable improvement at Mr. Ladd's hands; and one of the earliest installations of electric lighting afforded to the public was made under Mr. Ladd's supervision on the above system at the Liverpool Street terminus of the Great Eastern Railway.

Mr. Ladd was from the time of its formation a director of the Anglo-American Brush Electric Light Corporation (Limited),

and also of the Electrical Power Storage Company, and he took an active interest in the administration of these companies until almost the day of his death.

Mr. Ladd was of a kind and loving disposition, always ready to help others with advice and means. He died after a long and painful illness on April 16, 1885.

He was elected a Fellow of this Society on April 12, 1867.

JAMES LAWSON was born in London on January 28, 1847. Left an orphan when very young, he early determined to go to sea, and the profession he selected was throughout his life one for which he had a most ardent love. After several years spent on different vessels he, in 1870, joined the Royal Mail Company as fifth officer. In this service he distinguished himself by his thorough capabilities as a seaman, and by possessing an immense amount of knowledge of the physical geography of the sea, and in eight years he rose to the rank of captain. On February 15, 1885, in severe weather, he left New York, with an excellent staff of officers and a good crew, in command of the ill-fated steamship the *Humber*. Nothing has ever been heard of the vessel since, and she is supposed to have foundered.

He was elected a Fellow of this Society, 1883, May 11.

JAMES MCDOWELL was born at Ballymacarow, co. Down, Ireland. He was a graduate both of Trinity College, Dublin, and Pembroke College, Cambridge, and in both universities he earned high distinction in many ways. At Dublin he five times obtained first-class honours in science, besides the first silver medal in mathematics at the degree examination. At Cambridge, in spite of the disadvantages arising from very bad health, he took the highest places in his college both in classics and mathematics, and graduated as seventeenth wrangler. Since the period of taking his degrees, his time has been principally devoted to private tuition, and many past and present members of the University of Cambridge will grieve to hear of the death of their tried and able tutor. In 1863 he published "Exercises on Euclid and in Modern Geometry," which was one of the first Cambridge books in which such subjects as harmonic and anharmonic pencils and ranges, radical axes and centres, involution, poles and polars, and reciprocal polars were considered in an elementary geometrical manner. Mr. McDowell treated these subjects as much as possible by Euclidean methods, so as to render the book acceptable to those who were only familiar with the ancient geometry. He was also one of the original editors of the *Messenger of Mathematics* at its foundation in 1862. In 1867 he published a Mechanics for use in the elementary examinations of the University.

He died at Cambridge, on March 17, 1885, leaving a widow and four children.

He was elected a Fellow of this Society, January 10, 1862.

NICHOLAS MARTINDALE (youngest son of N. Martindale) was born in Liverpool, July 23, 1822, and resided in that neighbourhood for many years.

He was greatly interested in all scientific pursuits, and particularly in astronomy, to which at one period of his life he devoted much of his time, possessing in his observatory at Holmfield Street, Liverpool, a very fine telescope by Alvan Clark.

After his marriage, in 1863, he went to live in the neighbourhood of London, where he remained till within a few years of his death, when he returned to the North and died at Southport, April 6th, 1885, after many years of delicate health, sincerely regretted by all who knew him.

He was elected a Fellow of this Society, 1862, April 11.

COLONEL CHARLES RATCLIFF, formerly of Wyddington, Edgbaston, near Birmingham, was a younger son of John Ratcliff, Esq., of Birmingham, and brother of the late Sir John Ratcliff, who was mayor of Birmingham, and who received the honour of knighthood on the occasion of the visit of the Queen and Prince Consort to open Aston Park in 1858. He was called to the Bar at Lincoln's Inn in 1848, but never followed the legal profession actively, being a director of the Birmingham Banking Company, Limited. He kept some terms at Downing College, Cambridge, of which he was M.A. He was a Fellow of the Society of Antiquaries and a member of the Athenæum and National and Conservative Clubs. He also was a "Goldsmith," and as such was a freeman of the City of London. In 1867 he became Lieut.-Colonel of the Birmingham Rifle Volunteer Corps, but resigned in 1871. He was presented with a sword by the officers and privates of that corps. He took an active interest in the promotion and management of reformatory and industrial schools, a work in which he was associated with Lord Norton, Mr. M. Davenport Hill, the Rev. Sidney Turner, and others. The first Reformatory Conference, held in Birmingham in 1851, was largely promoted by Colonel Ratcliff, who acted as one of its secretaries, attending all its meetings from the first. He acted to the very last as secretary and treasurer to the Saltley Reformatory Institution, near Birmingham. He was appointed to the colonelcy of the Surrey Rifles, and on retiring he was allowed to retain his rank.

He took an active part in the first Social Science meeting at Birmingham in 1857, when he had Lord Brougham (the President) as his guest.

He died at Matlock Bank on August 28, 1885, and was buried at Edgbaston, Lord Leigh, Lord Norton, and many of his public and private friends attending.

Colonel Ratcliff married, in 1875, Helen, daughter of the late Sir William Jardine, Bart., F.R.S., who survives him without issue.

He was elected a Fellow of this Society, 1874, May 8.

ANTHONY ASHLEY COOPER, Earl of Shaftesbury, was born on April 28, 1801. He was educated at Christ Church, Oxford, where he obtained a first class in classics in 1822, graduated M.A. in 1832, and was created D.C.L. in 1841. Lord Shaftesbury's great position as a philanthropist has been so fully dealt with elsewhere that it is unnecessary to call lengthened attention to it here. In him has passed away the most eminent social reformer of the present century. It is not too much to say that he had acquired a world-wide fame as a philanthropist, and that his name is inextricably interwoven with many of the most humane movements of two generations. Pre-eminently the friend of the poor, the degraded, and the outcast, his generous sympathies and his ceaseless efforts on behalf of the classes in whom he took so deep an interest have given him a high place in the illustrious roll of benevolent Englishmen. It is interesting, and perhaps not a little singular, to note that one of the most steadfast and powerful friends which the humbler classes have ever had, as well as one of the most trusted, did not belong to their own order of the commonalty, but to the privileged order of the aristocracy.

Lord Shaftesbury never engaged particularly in any scientific pursuit. He had a general fondness for science, and was especially interested in astronomy, and in conjunction with his intimate and valued friend, Sir James South, he in early life devoted a good deal of time to astronomical study in the latter's observatory at Kensington.

An unfortunate exposure to east wind brought on an attack of inflammation of the lungs, to which Lord Shaftesbury eventually succumbed on October 1, 1885.

He was elected a Fellow of this Society on November 14, 1828.

JOSEPH SIDEBOTHAM, whose death took place at his residence, Erlesdene, Bowdon, on May 24, 1885, was descended from an old Cheshire county family. He was the younger of the two sons of Joseph Sidebotham, Esq., of Apethorne House, near Hyde, where he was born on January 17, 1824, we believe, only a few months before the death of his father; and was the grandson of John Sidebotham, Esq., of Hoviley. He was for some time a pupil of the famous Rev. Parr Gresswell, of Denton, with whom he continued a close friendship until Mr. Gresswell died at an advanced age. He subsequently went to Manchester business, and served a term with Nelson, Knowles & Co., whose printworks were at Tottington Mill, Bury, and in April, 1849, he joined as a junior partner of six members the firm of the Strines Printing Company, and continued in the company for twenty-eight years, and had been senior partner for many years when he retired in 1876. He remained in business long enough to see his firm the pioneer, on a large scale, in the use of alizarine, to the total discontinuance of the use of madder and its products, and the company early became celebrated for their beautiful scarlets, which for several years yielded large profits.

His cousins, John Sidebotham, Esq., of Kingston House, Hyde, and Edward Lowe Sidebotham, Esq., of Cheltenham and Shepley, left him large properties, including the Hyde and Haughton Collieries, and soon after their death he retired into private life in 1877.

Though well known and highly esteemed as a commercial man and as the head of the oldest calico printing firm in Manchester, he was probably even more esteemed as a man of considerable scientific attainments. He was for more than thirty years an active member of the Manchester Literary and Philosophical Society, and for a long period was a member of the council. Especially was he clever in the microscopical, astronomical, and photographic sections. With the late Bishop Prince Lee he may be said to have been the leader of the photographic section, and subsequently, with Lund, Brothers, Mudd, and others, he founded the Photographic Society, as with Grindon and a few other enthusiasts he founded the Field Naturalists' Society, and was its first treasurer. He was also an enthusiastic botanist. Grindon, in his "Walks and Wild Flowers," says of him, "The upper portion of the Tame Valley between Reddish and Hyde was successfully explored in 1840–42 by Joseph Sidebotham, of Apethorne, a townsman whom we have not more reason to be proud of as a naturalist of the most varied and accurate information, and as one of the most scientific and successful prosecutors of microscopical research, than as a singularly skilful artist in photography. It was Mr. Sidebotham who first drew the attention of Manchester naturalists to the freshwater algae of our district, and who principally determined their form and number. He also it was who collected the principal portion known up to 1858 of the local Diatomaceæ. During the five or six years he devoted to the botany of Bredbury, Reddish, and the banks of the Tame generally, he added no fewer than twenty-five species to the Manchester flora."

He was also an enthusiastic entomologist, and materially increased the list of species of coleoptera and lepidoptera found in his neighbourhood of Hyde, Strines, and Manchester; and he was no less proficient in the science of astronomy.

He was the very intimate friend of James Nasmyth, the famous inventor and no less eminent astronomer. It was to Joseph Sidebotham he first communicated his views of the "willow leaves" structure of the Sun, and many other papers which were first read to the Manchester Literary and Philosophical Society by Mr. Sidebotham.

Mr. Sidebotham was also a personal friend and frequent correspondent of Prof. Piazzi Smyth, the Astronomer-Royal for Scotland, and read some of his first communications on his researches at the Great Pyramid, illustrated by his own photographic views, before the members of the above Manchester Society.

He was too modest a man to care for titles or distinctions, and though he was a Fellow of the Royal Astronomical Society,

the Society of Antiquaries, and many other learned societies, he never used the titles.

He was also a county magistrate of Cheshire, a position he accepted only at the personal urgent request of Lord Egerton, the lord-lieutenant.

He founded, at a cost of some 20,000*l*., including the endowment and rectory, the beautiful church of St. Anne, Haughton.

He always took special interest in the poor boys and youths among his neighbours and workpeople, and gave up much of his leisure to their personal instruction by lectures and otherwise, and many have him to thank for such timely aid for their now comparatively easy and respectable positions in life.

He took great interest in the "Strines Journal," a manuscript work of science and art, conducted by his *employés*, and he frequently contributed articles and drawings to its pages; it now forms a ten years' history of Strines and the neighbourhood and their natural history, which could not easily be surpassed.

He was also a great lover of sacred music, a devoted admirer of Handel and Mozart, and was no mean performer on the organ, as his father was before him. For many years after the opening of Bredbury Church he was the honorary organist there, and did duty every Sunday at that church, the land for which and the large graveyard surrounding it was given by his cousin, John Sidebotham, who also contributed largely to its cost. Joseph Sidebotham made and erected with his own hands the sundial over the south door of that church.

He maried, in 1852, Anne, the only daughter of Mr. Coward, of Manchester, formerly of the firm of Melland & Coward; she died nearly three years ago. He leaves three sons and three daughters to mourn his loss. His remains were deposited by the side of his wife in the parish churchyard of Bowdon.

He was elected a Fellow of this Society on November 11, 1870.

Thomas A. Southwood, M.A., who died at Cheltenham on September 19 last, was born and educated at Devonport. His first step in life was an appointment in the Ordnance Survey in Ireland. He then proceeded to Cambridge, where he graduated in 1843 at the comparatively mature age of thirty-two; and in the same year, after having received and declined the offer of an important post in the St. Petersburg Observatory, he was elected to the Head Mastership of the Modern Department of Cheltenham College. This, the first departure from the old classical school methods, could not have been placed in better hands. Besides being a sound and practised mathematician, familiar with the methods and instruments of science, Mr. Southwood possessed a singular faculty for imparting knowledge; and the new military school, under his management, supplied Addiscombe and Woolwich from year to year with their most promising cadets.

After a brilliant and uniformly successful career of

thirty-six years, Mr. Southwood retired in 1879. He leaves behind him at his death a name and an example which will never be forgotten at Cheltenham College, where his surviving friends and pupils propose to erect a new library to his memory.

He was elected a Fellow of this Society on February 13, 1852.

JOHN WATSON was born in the village of Ireshopeburn, near St. John's Chapel, Weardale, on February 10, 1827. He was educated at the village school and at St. John's Chapel. From boyhood he showed a great taste for physical science, and was at all times most industriously given to habits of self-culture.

While still a youth he obtained a humble position in the chemical works of Mr. Hugh Lee Pattinson at Washington, and gradually rose through several minor posts to that of cashier in the office, and later on he became general manager of the works. In 1864 he left Washington to become the founder and managing partner of the chemical works of Messrs. Watson, Kipling & Co., at Seaham Harbour, on the coast of Durham. Though a most industrious worker at his profession, Mr. Watson found time to devote to astronomy, and he showed great genius in the construction, by his own hand and lathe, of telescopes and various optical instruments.

In March 1856 a paper, "On the Outer Ring of Saturn," written by Mr. Watson, was communicated by the Astronomer Royal to the Royal Astronomical Society, and this was followed in January 1857 by a note, "On the Occultation of Jupiter on January 2, 1857." In 1864 he communicated a note, "On a new Binocular Telescope," and since then he has contributed to the *Notices* from time to time, the last communication being "On the Satellites of Mars," in January 1882.

Mr. Watson was well known in the county of Durham as a popular lecturer on astronomy, one of his best known lectures being on the harmony of the Mosaic record of creation with the modern scientific revelations of astronomy and geology. Though not an orator, he had a happy way of imparting knowledge of dry scientific matter in everyday language.

He was familiar with the discoveries of modern science, being well read in the subjects of chemistry and geology, as well as astronomy, and he made meteorological observations for many years at Washington, which formed the subject of some papers on rainfall, &c., in the "Tyneside Naturalists' Transactions." His observatory at Vane House, Seaham Harbour, contains an 8-inch achromatic, with object glass, by Wray. He also worked with a 12-inch, by Messrs. Cooke, of York, and with reflecting telescopes of his own construction, the specula being ground and polished by himself.

Mr. Watson had been in his usual health up to October 30, on the evening of which he was seized with sickness, and, though the best medical aid was procured, the disease, intus-

susceptiou, proved fatal. He died on the afternoon of November 3, at the comparatively early age of fifty-eight, leaving a widow, two sons, and two daughters to mourn his loss.

Trained from childhood in the tenets of the Wesleyan faith, Mr. Watson was, up to the time of his decease, an active member, and loyal supporter of the United Methodist Free Church; but he was ever a man of broad and liberal views, and in his wealthier days gave much, in a quiet way, to various charitable objects.

As an employer of labour he was much respected by all his men, and as a member of various local boards of health and of education he was at all times courteous and useful.

He was elected a Fellow of this Society on November 13, 1857.

Thomas William Webb was born on the 14th day of December, 1807. He was the only son of a clergyman, the Rev. John Webb, rector of Tretire cum Michaelchurch, in the county of Hereford, a living in the gift of Guy's Hospital, which he held with the Vicarage of St. John's, Cardiff. The Rev. John Webb was a good classical and antiquarian scholar; the late Sir Henry Ellis described him as an eminent authority on Norman French, and he was frequently called upon to give evidence in Courts of Law with respect to the interpretation of early documents, but the father of the future astronomer was more particularly devoted to researches respecting the history of the West of England during the period of the Civil War. He had inherited a large collection of MS. matter referring to the Cromwellian period from Baron Pengelly, a connection of the Cromwells, in whose house Richard Cromwell, sometime Lord Protector of England, died. During the greater part of a long life the Rev. John Webb was occupied in preparing a "History of Herefordshire during the Civil War"—a work which, though he lived to the age of ninety-three, he never finished, but his son, Thomas William Webb, with filial devotion, completed and published it after his death. In the preface the son speaks of the long years of thoughtful study which his father had given to the work, and of the dread of inaccuracy or precipitation which prevented its earlier publication. This careful and conscientious spirit was fully inherited by the son, and is a decided feature of his astronomical writings. Although the father did not finish his great work on the "History of Herefordshire," he completed several memoirs for the Society of Antiquaries, and edited more than one volume for the Camden Society, though one of these, "The Military Memoirs of Colonel John Birch," a Cromwellian leader, was left only partly finished, and was completed by his son.

Thomas William Webb's mother died when he was still a child, and his father devoted himself to the boy's education. He was a painstaking, carefully precise boy, preternaturally old and studious, as might have been expected from the child com-

panion of such a father, surrounded by books and MSS. The boy showed some taste for experimenting, and delighted in books on electricity and physics—Natural Philosophy books, as they were called in those days—enjoying them more than a fairy tale. He did "not consider Euclid to be work," and would no doubt have taken to mathematics, but his father did not encourage such proclivities, desiring to make his son a scholar; a term which was identified in his mind with Latin and Greek verse-making and certain refinements of Latin composition, at which the boy worked hard but did not make the progress that his father had hoped. In 1826 he was entered at Oxford and became a Fellow Commoner at Magdalen Hall. In 1829 he took his degree, taking a second class in Mathematical honours. In after years he would excuse himself to younger friends for his University life, saying that he had been very idle, spending most of his time in desultory reading in the libraries. But he was no doubt preparing himself in a satisfactory manner for his future life, perhaps in a much more satisfactory manner than if he had strictly adhered to the University course. From his own account he does not seem to have had bad health, though he was not strong. In after years his strength was decidedly above the average, and he would tramp over the hills of his mountain parish as few clergymen of seventy can.

After leaving Oxford he was ordained a Curate on the 1st of August, 1829, in Hereford Cathedral, and was licensed to the curacy of Pencoyd, where he worked two years, and was not ordained to Priest's orders till the 7th of August, 1831, when he became Minor Canon and Precentor of Gloucester Cathedral. After some ten years' work in Gloucester he returned to Tretire and worked as curate to his father for nearly twenty years. In 1843 he married Henrietta Montague, daughter of Mr. Arthur Wyatt, of Troy House, Monmouth. The marriage took place on the 16th of May at Michel Troy church. In 1852 he was given the living of Hardwick, a large though thinly populated parish near to the Welsh border and Black Mountain district.

Here he wrote "Celestial Objects for Common Telescopes," a book which has made the name of the parish familiar to astronomers all over the world. It may probably be said, without exaggeration, that this book has done more to introduce the possessors of telescopes to the remarkable objects in the heavens, and to create observers, than any other book which has been written. It has no doubt exercised an important and very valuable influence on the method of describing observations. Mr. Webb was greatly attached to the Rev. W. R. Dawes, and would recommend others to take Mr. Dawes's method of describing his observations as their model. Both men were particularly careful and conscientious in their statements, judiciously choosing their language so as to avoid any slight exaggerations as to the accuracy of their estimates or any undue generalisations from isolated facts. Both men were careful to give credit to others, and frequently

summed up very concisely and happily the results of prior observations. In reading any astronomical description by either Mr. Dawes or Mr. Webb, the reader is impressed by the unpretending precision of their style, while he is made fully to appreciate the doubtfulness of the phenomena of which they themselves felt doubtful.

In addition to the "Celestial Objects," which went through four editions, being greatly improved and enlarged by diligent revision at each edition, Mr. Webb wrote largely for periodicals on astronomical subjects. His articles will be found in "Fraser's," "The People's Magazine," "The Intellectual Observer," "The Student," "The Popular Science Review," "The Argonaut," "The English Mechanic," "Nature," and "Knowledge."

His private correspondence with amateur astronomers was very large. He patiently and generously gave his time to advising them with regard to their instruments and the course of work they should undertake. Few things pleased him more than to help in stirring up the enthusiasm of an observer in some distant colony. There must be a large amount of his correspondence treasured up in all parts of the world. His letters were always written in a neat, small hand, which enabled him to put a great deal into the page; and they were frequently illustrated with charming little drawings and enlivened by the quaintest humour, which of its kind is as curious as De Morgan's. His modesty was striking and most unaffected. This seems to have impressed all his friends, as well as his courtesy and obliging kindness as a correspondent, which made him very widely valued and beloved.

Like his friend Mr. Dawes, Mr. Webb was a good draughtsman. His drawings illustrating his observations were made on a smaller scale than is commonly adopted by telescopic observers, as he thought that in making large-scale drawings the observer has a tendency either to fill in more detail than he has actually observed, or to give an appearance of clear definition to details which have been only traced with difficulty. In representing lunar objects, where the multiplicity of clearly traceable detail overpowers the observer, Mr. Webb usually confined himself to diagrams or mere outline maps. In drawing comets, however, where the difficulty lies in faithfully representing delicate differences of brightness, he adopted rather a larger scale than other observers. The plates of the great comet of 1861, given in vol. xxii. of the *Monthly Notices*, do not do justice to his original drawings. His observations of this comet were very striking.

On the evening of June 30, 1861, while standing with his wife in the garden of the Parsonage at Hardwick, he noticed some faint streamers diverging from the nucleus of the great comet then visible. At first he took them for faint narrow lines of cirrus cloud; but their direction pointing to the nucleus of the comet attracted his notice, and on giving closer attention to them he

found that they were slowly closing up like a fan, always pointing to the nucleus of the comet. The observation is described in vol. xxii. of the *Monthly Notices*, and seems to have been an actual observation of the Earth's passage through the tail of the comet. There were two other observers who were fortunate enough to notice the same phenomenon—one, Mr. Williams of Liverpool, and the other in the Antipodes.

In a volume entitled "The Industrial Progress of New South Wales," published by authority of the Colonial Government, is a paper by Mr. Tebbutt, in which he says that while observing in Australia, on the morning of July 1, 1861 (*i.e.* really in the afternoon before sunset of our June 30) he noticed the widening out of the branches of the tail of the comet then visible. He remarks that this observation is very interesting when taken in connection with the announcement made by Mr. Hind that it appeared probable that in the course of June 30, 1861, the Earth passed through the tail of the comet at a distance of perhaps two-thirds of its length from the nucleus.

Mr. Webb and Mr. Williams observed the closing up of the streamers of the tail while Mr. Tebbutt in Australia observed the opening out of the streamers a few hours before, as the Earth entered the tail.

On Sept. 7, 1884, Mrs. Webb died from apoplexy. Her husband was completely prostrated by the sudden blow, and his health gradually failed, till he died, eight months after, on May 19, 1885, at Hardwick, the parish to which he had been devoted for nearly thirty years. If he had lived to December, he would have completed his seventy-eighth year.

In 1882 he was appointed one of the Prebendaries of Hereford Cathedral, an office which only required a month's attendance during the year, and would have separated him but little from his beloved parish.

He was elected a Fellow of this Society 1852, Jan. 9.

A. C. R.

WILLIAM WRAY was born at Whitby, in Yorkshire, on December 6, 1829.

His father, who was a sea-captain, wished to take him to sea, but his mother objecting, he was articled to a solicitor. He had a great love for astronomy and optics, and amused himself by constructing some reflecting telescopes, but not being satisfied with these, he turned his attention to the refractor, and made numerous experiments with a view to dispensing with flint glass, which was expensive, and at that time difficult to procure of good quality. These experiments were not practically successful.

Not liking the legal profession, he came to London in the year 1850, and commenced the practice of an optician, devoting himself at first chiefly to the construction of microscope objectives, and was perhaps the first professional optician who used

the single front lens for the higher powers, in place of the older triple combination.

He spent much time in experiments for the reduction of the secondary spectrum, and succeeded in making object glasses practically free from outstanding colour; but these were unfortunately not permanent, owing to the fact that only fluids had the required dispersion, and in consequence of their contraction and expansion it was found to be quite impossible to retain them between the lenses for any great length of time.

He was very successful in the construction of both telescope and microscope objectives, and made a great improvement in the former by the substitution of light in place of the dense flint glass as usually used, thus lessening the secondary spectrum in a marked degree.

Owing to ill health he had been unable to take an active part in the business for some years.

He was elected a Fellow of this Society on January 10, 1862.

Colonel William Yolland, C.B., F.R.S., was born on March 17, 1810, at Merrifield, Plympton St. Mary's, Devon. In early life he was admitted into the Royal Academy at Woolwich, where he obtained his commission in the Royal Engineers in 1828.

He rose by regular promotion until he became lieutenant-colonel in 1855, and a brevet colonel in the army in 1858. Colonel Yolland early developed a faculty for mathematical and geodesical studies, which he cultivated with signal success. His abilities found scope in Canada shortly after his admission to the Royal Engineers, and he was subsequently employed at the Ordnance Survey at the Tower of London, at Southampton, Dublin, and Enniskillen. During this interval he superintended the publication of astronomical observations made with Ramsden's zenith sector, and afterwards with Airy's, the latter being for the purpose of determining the latitudes of various trigonometrical stations in Great Britain and Ireland. He also compiled an account of the measurement of the Loch Foyle base, which was made during the years 1827–29. The article on Geodesy which forms part of the mathematical text-book used at the Royal Military College was written by Colonel Yolland at the express request of Colonel Harness, who was at that time Assistant Inspector-General of Fortifications. In 1854 Colonel Yolland was appointed one of the Inspectors of Railways under the Board of Trade, in which capacity his name has been often before the public.

While in the service of the Board of Trade he was appointed superintending engineer of the Ramsgate Harbour Works, but this appointment he resigned, after holding it only a few months.

In 1856 his wide experience and sound judgment led to his

being selected as the engineer member of the Commission appointed by the Secretary of State for War to consider the best mode of reorganising the system of training officers of the scientific corps, with the special intention of abolishing patronage and opening the commissions in those corps to competition. The Commissioners, the other two of whom were Colonel W. J. Smith, R.A., and the Rev. W. C. Lake, visited France, Prussia, Austria, and Sardinia; and after studying the methods of appointment in use in those countries, drew up a report, which was printed by order of the House of Commons.

On the retirement of Sir Henry Tyler from the office of Chief Inspector of Railways under the Board of Trade, he became the senior inspector, and held this appointment at the date of his death, having thus been thirty-one years in the service of the Board of Trade.

He received the distinction of C.B. (Civil) in 1881. Colonel Yolland died at Baddesley Vicarage, Atherstone, Warwickshire, where he was making a temporary stay with his family, on September 4, 1885.

He was elected a Fellow of this Society on February 14, 1840.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

The regular meridian work of this Observatory has proceeded without interruption throughout the year, and has been continued on the same lines as before. 5,374 transits and 4,664 meridian zenith distances were observed in the year 1885, the total number of stars observed being 1,415. A considerable number of transits were observed by eye and ear, the chronograph having been out of use during January, February, and part of March, whilst various repairs necessitated by its long and constant use, and some improvements suggested by experience, were carried out by Messrs. E. Dent & Co. As the observers have, under ordinary circumstances, little practice in eye-and-ear transits, it has been made a rule to observe two clock-stars by this method on each night of observation with the transit circle. The observations with the "reversion prism" have been continued as in 1884, and the existence of a small personal error depending on the direction of motion would appear to be fairly well established, though the quantity is so small that many more observations will be required for its accurate measurement. The altazimuth has also been used as follows to investigate this "personality:"—two transits of the same object are observed in close succession, and the eyepiece is rotated through 90° (reversing the direction of apparent motion) at the middle wire of the first transit, and back to its original position at the middle wire of the second, giving virtually a pair of symmetrical transits of the object with apparent motion in opposite directions; or, with a rotation of 45° instead of 90°, a comparison of horizontal and vertical transits may be obtained. The results are satisfactorily in accordance with those given by the transit-circle.

A special instrument has been devised for the further investigation of the whole subject of "Personal Equation," by means of which transits of limbs of an artificial sun and moon or

artificial stars can bo observed with the transit-circle, and the actual times of transit recorded automatically on the chronograph. The artificial objects are apertures in a vertical plate, which is placed in the focus of an object-glass of about 7 inches aperture and 50 feet focal length (attached to the dew cap of the transit-circle when horizontal and pointing north), and is carried smoothly by clockwork from east to west or west to east, at a rate which may be varied at will from that of a close circumpolar star to three or four times that of an equatorial star. The apertures in the plate are illuminated by a mirror placed behind, which reflects the Sun's or Moon's rays to the object glass. The automatic registration is effected by the contact of insulated platinum studs affixed to the plate and corresponding to the artificial objects, with other fixed studs corresponding to the wires of the transit-circle. The instrument is now complete, and a few observations have been made with it.

The mean error in R.A. of Hansen's Lunar Tables with Professor Newcomb's corrections is $+0^{s}\cdot028$ for the year 1885, as deduced from 105 observations with the transit-circle.

Three determinations of flexure of the transit-circle in 1885 gave results $+0''\cdot08$, $-0''\cdot08$, and $0''\cdot00$ respectively; the mean of five determinations in 1884 was $+0''\cdot18$, and of five in 1883, $-0''\cdot49$. Since 1879 no separate correction for flexure has been applied.

The apparent correction to the nadir observation deduced from reflexion observations of stars in 1885 is $-0''\cdot27$, as compared with $-0''\cdot45$ in 1883, and $-0''\cdot36$ in 1884.

The equality of successive intervals of the micrometer screws of the six transit-circle microscopes was investigated in March, and it was found that though there was evidence of considerable wear in the individual screws, the effect was eliminated from the mean (within $0''\cdot05$) by the method of using them, the action of the spring being in opposite directions for the micrometers of each pair. It has been decided, however, to replace them by new steel screws, which were constructed by Mr. Simms, and brought into use on January 1, 1886, the four supplementary microscopes being used in the preceding month, whilst the new screws were being applied to the six ordinary micrometers.

The altazimuth observations of the Moon in the first and last quarters have been continued through 1885. The reversion-prism eyepiece has been used to reverse the apparent direction of motion in one position of the instrument for each double observation of azimuth or zenith distance, so as to eliminate personality depending on the direction of motion.

With the reflex zenith tube 41 transits of γ *Draconis*, at temperatures ranging from 45° to 71°, and 6 transits of 9 *Aurigæ*, at temperatures ranging from 41° to 56°, have been observed; these observations, and those made in 1883 and 1884, seem to show that the temperature correction to an interval of the wires is not well enough marked to explain the anomalous parallax of

γ *Draconis* deduced from observations made with this instrument.

The Lassell Equatorial is now in working order, and has been used during the past year for observing occultations and phenomena. Various small additions and improvements have been required; a lamp has been fitted for illuminating the field, a new plane mirror (silver on glass) has been supplied by Mr. Calver, and the apparatus for slow motion in R.A. has been modified, so that it can be used without disconnecting the clock. The definition obtained with this instrument is occasionally extremely good, but air currents, occasioned by the heat of the observer's body, sometimes give trouble.

On the recommendation of the Board of Visitors, the Treasury have sanctioned an important addition to the optical means of this Observatory in the shape of a refractor of 28 inches aperture and 28 feet focal length, to be mounted on the south-east equatorial, in place of the present telescope of $12\frac{3}{4}$ inches aperture. With this instrument the number of stars available for observation with the spectroscope should be largely increased. The work of constructing and mounting the object-glass has been entrusted to Mr. Howard Grubb.

Comet *a* 1885 has been observed on one night; Comet *c* 1885 on three nights; Comet *d* 1885 on three nights; and Comet *e* 1885 on one night with the equatorials. Twenty-seven occultations of stars by the Moon as well as the occultation of *Uranus* on November 30 have been observed, in most cases by two or three observers, and sixty-three phenomena of *Jupiter's* satellites. The plurality of observers has thrown some light on the probable error of these observations, which does not seem to be appreciably greater for occultations or transits of satellites than for eclipses.

The following spectroscopic observations have been made with the half-prism spectroscope mounted on the S.E. equatorial:—234 measures of the displacement of the F line in the spectra of 43 stars; 53 of the *b* lines in the spectra of 11 stars; together with 70 comparisons of the hydrogen or magnesium lines with the corresponding lines in the spectrum of the Moon or of the Sun, 15 measures of the displacement of the *b* lines in the spectrum of *Venus*, 18 measures of the relative displacement of the *b* lines at the E. and W. limbs of *Jupiter*, and 6 at the N. and S. limbs, also 10 of the relative displacement of the same lines at the preceding and following ansæ of *Saturn's* ring, as a check on the general accuracy of the results for star motions The spectrum of the new star in the great nebula in *Andromeda* was observed with one or other of the spectroscopes of the Royal Observatory on five nights, that of Mr. Gore's *Nova Orionis* on one night. The chromosphere was completely observed on six occasions, and the spectrum of the large sun-spot, which developed so remarkably from July 5 to July 11, on one occasion.

In the year 1885, 428 photographs of the Sun were taken at Greenwich on 206 days. The Greenwich photographs have been

supplemented by photographs, taken on 79 days, received from Dehra Dûn for the period January to October 16, 1885.

The spectroscopic observations are completely reduced to the end of 1885 and are ready for press. The photographs of the Sun are completely measured and reduced to the end of 1885.

A large number of measures of areas and positions of spots have been made during the year 1885 for determination of the probable error of a single measure, and there is every reason to be satisfied with the results obtained.

The magnetical and meteorological observations are continued generally on the same plan as in former years. Absolute determinations of magnetic declinations are made daily, of horizontal force monthly, and of dip frequently during each month. And by means of photography a continuous record is kept of the variations of declination, horizontal force, and vertical force, as well as of the earth currents which appear in two independent lines of wire. The magnetic results are printed in such shape as to give as much information as possible in regard to magnetic movements, and in all cases of unusual motion of any significance reproductions of the original curves are given, those of the different elements being placed one under the other, so that they may be readily compared. The complete registration of magnetic and solar phenomena in one establishment gives, it is believed, special advantages as respects the comparison of these related phenomena.

With a view of obtaining greater uniformity of temperature in the magnet basement, a line of pipes has been laid underground, for its ventilation by air which has acquired the temperature of the soil at a depth of 10 feet.

The meteorological registers comprise photographic record of the variations of the barometer, of the dry and wet bulb thermometers, and of atmospheric electricity, with continuous automatic record of the deviation, pressure, and velocity of the wind, and of the amount of sunshine and rainfall. Observations are also made daily of the temperature of the soil at depths of 3, 6, 12, and 24 feet respectively below the surface. Results deduced from the meteorological observations and records are printed in the annual volume so far as seems desirable.

At the beginning of the year 1886 the new photographic thermometer apparatus for registration of the temperatures of the air and of evaporation was brought into regular use. It is proposed for a time to continue the records both with the old and new apparatus for the purpose of making comparison between them. Observations of the temperature of the air in an exposed situation on the roof of the Magnet House were also commenced at the same time.

Watch is kept for a few of the principal meteor showers, though great attention cannot be paid to work of this kind. Observations were made, as far as possible, of the meteors in connection with Biela's Comet on November 27, 1885, but the weather at Greenwich was extremely unfavourable.

The volume of Greenwich Observations for 1883 was distributed in September last, and the printing of that for 1884 is well advanced, though there has been some pressure of work in this connection owing to the long-continued maximum of Sun-spots, and the undertaking of several minor investigations bearing on the results.

The heated-chamber for testing Government chronometers has been supplied with a contrivance, invented by Mr. Kullberg, for automatically regulating the temperature; by means of this instrument it has been found possible to maintain the temperature constant within narrow limits. A double casing to the chamber, packed with a non-conducting material (slag-wool), materially contributes to constancy of temperature.

In the summer of 1885 Commander Moore and Lieutenant Douglas, of the Royal Navy, made a series of observations at this Observatory for a comparison of the respective merits of sextants and small transit instruments for determining local time. In connection with this work a telegraphic determination of the difference of longitude between Greenwich and Gibraltar has been made under the superintendence of the Hydrographer, the local time being determined at each station by means of the sextant. Sets of signals were exchanged between Greenwich and Gibraltar on three days, the signals at Greenwich being observed by four or five observers.

Armagh Observatory.

The building for the new equatorial was erected in July last, about 100 feet south of the Observatory. It is similar to that supplied by Mr. Grubb for the Natal Observatory, but is of rather more substantial construction, with a carefully planed cast-iron wall-plate, on which the dome moves on six "canted" wheels. The dome is covered with papier-mâché, rivetted to the iron framework and stitched together with copper wire. A small porch affords room for the clock, battery, shelves, table, &c. Under this "Robinson Memorial Dome" was next erected an equatorial refractor by Mr. Grubb, having an excellent object-glass of 10 inches aperture and 10 feet focal length. The declination circle can be read from the eye end, and both it and the R.A. circle can be illuminated by small incandescent lamps worked by a two-cell bichromate battery. There is a third lamp over the table in the porch to throw light on maps or working lists.

The carpenters' and painters' work was not finished till the end of September, when the instrument was at once adjusted and brought into use. A series of micrometric observations of nebulæ has been commenced with a small micrometer, having steel bars instead of wires, and requiring no illumination. This micrometer has only one screw, but it is attached to a slipping-

piece, which moves it bodily in the direction of the position wire. More delicate measures will be made with a bifilar micrometer with electric illumination, which forms Mr. Grubb's contribution to the Robinson Memorial, and which will shortly be ready for use.

The printing of the "Second Armagh Catalogue of 3,300 stars" has progressed very slowly, and is not yet finished. It is, however, hoped that it will be distributed in the spring. It has revealed some interesting cases of proper motion, of which an account will soon be laid before the Society.

Cambridge Observatory.

The observations during the year have been almost exclusively made with the meridian circle, for the purpose of determining instrumental errors, and of supplying the places of stars which had either been passed over in the regular zone work of previous years, or had not been observed the prescribed number of times.

2,635 meridian observations have thus been taken in 1885, all read off with four microscopes, and all, with very few exceptions, taken at five or seven wires. 1,936 of these observations are of stars within the zone; 583 of standard clock stars; 60 are observations of *Polaris* above the pole, involving 134 circle readings; and 56 of *Polaris* below the pole, involving 118 circle readings.

The number of nights suitable for observing zone stars was 92, which is rather below the average.

Collimation, level, and nadir point were taken 189 times.

The entire number of observations of zone stars now amounts to 43,450. The apparent Right Ascension and North Polar distances are deduced from these up to June 5, 1885.

The mean R.A. and N.P.D. for January 1 are obtained up to 1880, February 17. The reductions to epoch are progressing as fast as time and the pressure of the work will allow.

The level and collimation are computed to the end of 1885.

The mean level error for the year is $-3''{\cdot}54$, a very slight increase negatively on that of the previous year—so slight, indeed, that the apparent change may be due to errors of observation.

A large number of observations have been made for the purpose of ascertaining the errors of division of the west circle. An apparent discrepancy between the zenith and nadir points is now undergoing investigation.

A fresh determination of the coefficient of flexure was made by means of observations extending from May 29 to July 17.

The final result from 200 observations of the north and south

collimators gives for the arc from north horizon, through zenith, to south horizon

$$180° 0' 1''{\cdot}00 \pm ''{\cdot}018$$

instead of 180°.

The correction of the circle reading for flexure, therefore, supposing it to vary as the sine of the zenith distance, will be

$$-0''{\cdot}50 \sin z,$$

when z is the zenith distance, + when S, − when N; which is sensibly less than the former result.

Dunsink Observatory.

During the past year the South Equatorial has been employed as usual in observations on Stellar Parallax. A series of measures from *Nova Andromedæ* to two other stars in the vicinity have also been carried on as long as the *Nova* remained visible.

The meridian circle and chronograph have been employed during the year in observing the list of southern stars mentioned in former reports. The majority of those still unobserved at the beginning of the year come on the meridian at night during the summer months, and as the assistant, Mr. Rambaut, was unable, from the effects of an accident, to observe for a considerable time during May and June, many of them have been again omitted.

Towards the end of the summer a new working list was compiled, consisting of stars with proper motions greater than $0''{\cdot}2$ annually. These were taken chiefly from Struve's "Positiones Mediæ," Argelander's list of 250 stars in Vol. VII. of the "Bonn Observations," and the list of stars given by Dr. Robinson in the Introduction to the Armagh Catalogue for 1840, along with some others taken from the Catalogues of Mr. Main and Mr. Stone in the "Memoirs of the Royal Astronomical Society." This list, with the former one, has been in use since September.

During the year the right ascensions of 730 stars and the declinations of 413 have been observed.

For the determinations of the clock error and the azimuth error of the instrument the fundamental stars of the "Berliner Jahrbuch" are used. Of these 273 transits of time stars and 67 of polar stars have been observed. The error of collimation of the instrument has been determined 168 times, the level error 112 times, and the error of runs of the microscopes 86 times. The nadir point has been observed 170 times, but since September the declinations of standard stars from the "Berliner Jahrbuch" have been observed in addition as a check on the accuracy of the nadir readings, two or more being observed each night for this

purpose. The mean of the determinations of the nadir point by both methods is that used in the reductions. Early in January, owing to a web which had grown over them, it became necessary to clean the spider lines in the meridian circle. This was done on January 5th, and the same corrections to the middle wire as before were used in the reductions. In August it was recognised that the wires had been disturbed by the process of cleaning, and that it was necessary to determine their distance over again. For this purpose 23 transits of polar stars were taken on 19 nights between August 11th and December 10th, but the majority of these, having been broken by clouds and being otherwise defective, the final intervals were made to depend on seven complete transits of *Polaris*. The wire distances were found so changed from what they had been before, that it was necessary to go back over all the reductions which had been done up to that time, and a complete set of new tables for reducing lateral wires to the middle had to be computed.

Royal Observatory, Edinburgh.

During the year 1885 the daily time-signals by ball and gun, as well as the control of certain mean-time clocks in the city, by original star observations in and electric currents from the Royal Observatory, Edinburgh, have been kept up as usual. Also the computing of the meteorological observations at fifty-five of the stations in Scotland of the Scottish Meteorological Society, and then furnishing the resulting numbers with remarks upon them to the Registrar-General of Births, Deaths, &c., in Scotland, for that officer's monthly and quarterly reports, where they have been duly printed.

A still more directly important work during the last eleven months has been the resumption of the printing of the "Edinburgh Star Catalogue and Ephemeris for 1830 to 1890." This step was rendered possible by an arrangement made last February with the Lords Commissioners of H.M. Treasury by the Right Honourable Sir William Vernon Harcourt, then Home Secretary, and by consequence Governmental Chief of the Observatory.

The printing began immediately thereafter, has continued without cessation up to the present time, has reached from 4^h to 17^h Right Ascension; and the astronomer has been much indebted to the unfailing care and rigorous severity with which the two assistant astronomers, Mr. Thomas Heath, B.A., and Mr. H. Ride, have day by day read the proof-sheets and revises against the original manuscript calculations, as well as the fair copy prepared for the printer to work by.

In the month of June the astronomer communicated to the Royal Society, Edinburgh, three successively and independently observed solar spectra, each extending through 60 double quarto

plates. The Society has had them photo-lithographed on a rather reduced scale, and they are expected to appear in the forthcoming volume of *Transactions* (xxxii.), before the end of the present month.

Glasgow Observatory.

The astronomical work at the Glasgow Observatory during the past year has been considerably impeded by the exertions necessarily made for the purpose of placing upon a satisfactory footing the meteorological operations of the establishment. From the beginning of 1868 a system of meteorological observations by the use of self-recording instruments had been conducted at the Observatory at the expense of the Meteorological Office in London. Early in 1883, however, the authorities of the Meteorological Office announced to the Glasgow Observatory, and also to several of the other observatories affiliated to the Office, their intention of withdrawing their support from the establishments at the close of the year, but they liberally offered to place a complete set of instruments at the disposal of any observatory provided an adequate fund was raised by local efforts for the continued prosecution of the observations. The final result, in so far as the Glasgow Observatory is concerned, has been satisfactory. By the co-operation of the Town Council and the Clyde Trustees with the authorities of the University of Glasgow, the maintenance of the meteorological operations has been secured. The connection with the Meteorological Office has also been re-established to a considerable extent as in former years. The astronomical operations during the past year have been necessarily confined to observations of a select list of stars with the transit circle.

Kew Observatory of the Royal Society, Richmond.

The sketches of sun-spots, as seen projected on the photo-heliograph screen, have been made on 176 days, in order to continue Schwabe's enumeration.

422 observations of solar and sidereal transits have been taken for the purpose of keeping correct local time at the Observatory.

In consequence of the increasing number of sextants sent to the Observatory for examination, it was found desirable to provide special accommodation within the building for the work. As the room known as the Pendulum-room was unoccupied, it was resolved to convert the apartment into a Sextant-room, and accordingly the Cooke testing apparatus was dismounted from the South Hall and erected in it. Four careful redeterminations

were then made of the angles between the collimators, and they were found to have been unaffected by transfer of the apparatus to the new position.

The arrangements for rating of watches have been continued during the year with great success, and up to the present 397 watches have been tried, of which 41 were submitted by the owners and 356 by the manufacturers or dealers.

The watches received during the year were entered for testing in the following classes:—For class A, 339; class B, 44; and class C, 14. Of these, 98 failed to gain any certificate; 13 passed in C, 111 in B, 169 in A, and 6 obtained the highest possible form of certificate, the class A, "ESPECIALLY GOOD."

In July, owing to the numerous requests from manufacturers and others, a system of awarding marks to class A watches, indicating the degree of relative efficiency exhibited during trial, was adopted, being based upon plans already in use in the Geneva and Yale Observatories. In it the number of marks awarded to an absolutely perfect watch is a hundred, made up as follows:—forty for a complete absence of variation of daily rate, forty for absolute freedom from change of rate with change of position, and twenty for perfect compensation for effects of alteration of temperature.

As, however, the trials already in use do not comprise a test for the going of travellers' or explorers' watches, experiments are in progress with a view of constructing apparatus to test the behaviour of watches when subjected to such motion as they experience in the case of daily wear and travelling, in order to make a special examination on this point for watches submitted for trial by the Royal Geographical Society.

A series of tests for pocket chronographs has also been introduced by special request of the Cyclists' Union.

The committee have also in contemplation the rating of marine chronometers for the public, and for that purpose a chronometer oven, constructed after the model of the apparatus at the Royal Observatory, Greenwich, for the Board of Trade some years ago, has been placed at their disposal by that department, and is now erected at the Observatory.

Enquiries have been instituted as to the various methods of rating at the Royal Observatory and at the Observatories at Liverpool (Bidston), Hamburg, Wilhelmshaven, Kiel, Geneva, Washington, and Yale, with the view of enabling the committee to decide upon the most suitable system to be adopted by them.

The usual magnetical and meteorological observations and reductions, and also the verification of instruments, operations to which the attention of the Observatory is mainly directed, have been carried on as formerly.

Liverpool Observatory, Bidston, Birkenhead.

The work has been of the same character as in previous years. Careful attention has been given to transit observations for the determination of clock errors and to the communication of accurate time to the port. The time gun on the Morpeth pier has been fired at 1^h p.m. daily, Sundays excepted. No instance in which the gun has failed to fire has occurred during the past year, and the flash has in each case agreed with the time shown by the normal clock in the chronometer room. The daily comparisons of clocks and chronometers have been made as heretofore. Two hundred and sixty-four chronometers have been tested during the past year, and records of the performance at sea of the chronometers of the Pacific Steam Navigation Company during twenty-six voyages of their ships from Liverpool to Valparaiso and back to Liverpool have been received. Each ship carried three chronometers, and by giving equal weight to each of the three the mean error of longitude for an average voyage of one hundred and one days was under three miles.

No change has been made in the meteorological work. Telegrams have been sent daily to the Meteorological Office and to the Liverpool Underwriters' Association. Weekly results have been sent to the Medical Officers of Health for Liverpool and Birkenhead, and to the Registrar-General, to whom monthly results have also been forwarded.

In May last the late Mr. John Hartnup retired from the post which he had held for nearly forty-two years with so much credit to himself and advantage to the mercantile marine of the Port of Liverpool, and his son, Mr. John Hartnup, jun., for many years Assistant at this Observatory, was appointed Director.

Radcliffe Observatory, Oxford.

The following have been the subjects of observation during the year 1885:—

With the Transit Circle:

1. Observations of stars to the seventh magnitude inclusive between 115° N.P.D. and the Equator.

2. Observations of the Moon, which are continued throughout the lunation, and regularly compared with the Right Ascensions and North Polar distances of Hansen's Lunar Tables. Such comparisons have been generally discontinued, and these results appear, therefore, to have a special value in keeping distinctly before astronomers the extraordinary character of the change between the results of observation and theory which took place about 1864, and has led in the following twenty-two years to

discordances in mean longitude between Hansen's Tables and observation of more than fifteen seconds of arc.

3. Observations of the Sun.

4. Reflexion observations to test the freedom of the instrument from systematic errors.

The following table gives the number of observations made during 1885:—

Transits, 3,500.
Circle observations, 3,440.

These totals include:

Observations of the Moon on 58 days.
„ „ „ Sun „ 90 days.
35 Reflexion observations of stars.
460 Determinations of nadir point.
2 Durations of passage of Moon's diameter.
4 Vertical diameters of the Moon.
4 Observations in R.A.
6 „ in N.P.D. } of *Nova Andromedæ*.

With the extra-meridional instruments:

31 Determinations of the magnitude of *Nova Andromedæ* from Sept. 9 (8th mag.) to Dec. 10 (14th mag.) [see *R.A.S. Notices*, vol. xlvi. No. 2].
25 Observations of 15 occultations of stars by the Moon.
1 Observation occultation disappearance of *Uranus*.
2 Observations „ reappearance „ „
5 „ of 3 eclipses of *Jupiter's* IV. satellite.
Measurement of bright solar halo with parhelia on Dec. 30.

The volume for 1882 has been printed and distributed.

The volume for 1883 is nearly ready for press.

The observations made in 1884 are completely reduced.

The observations made in 1885 are nearly reduced to the end of the year.

Oxford University Observatory.

During the past year the attention of the observers has been absorbed by the completion of the *Uranometria Nova Oxoniensis*, and by passing this work through the press. Independently of much preliminary work, commencing in October 1881, the first published determination of magnitude was made in December 1881, the last was made in October, 1885, and the entire work was published at the end of November of that same year.

The *Nova* in the nebula of *Andromeda* and that in *Orion* have been constantly observed, and a few measures were made of the translucency of discs of optical glass, which remain for communication to the Astronomical Society. The only other work prosecuted at this Observatory consisted in many lectures delivered by the Professor to students in the University, and much time was also devoted by the assistants to the instruction in practical work.

It is proposed now to devote the instruments in the Observatory to photography and spectroscopy. In the first place, two constellations will be selected—*Cassiopeia* and *Lyra*—with the view of giving what may be termed their natural history, in respect of brightness, configuration, and constitution, including, if possible, the motion of the brighter stars in the line of sight. The photographs will be confined to small plates, including an area of about one degree square, with the view of obtaining charts admitting of as accurate measurement as with a micrometer applied directly to the sky. The experiment is somewhat formidable, but will be steadily prosecuted.

Temple Observatory, Rugby.

During the year 1885 the usual attention has been given on fine evenings to members of the school, and the Observatory has been open for such purpose seventy-eight times.

In original research, Mr. Seabroke has been giving up nearly the whole of his available time to the spectroscopic measurements of the motion of stars in the line of sight. A very considerable period has been absorbed in alteration of the optical arrangements, which are not now considered final, and a spectroscope, with bisulphide of carbon prisms, is being constructed for trial.

Besides trial observations, 65 sets of measures, of an average of six each in each set of 33 stars, have been made.

The measurement of double stars has been continued, but, owing to other work, the progress of former years has not been equalled; 163 sets of measures of 94 stars have been made by Mr. Percy Smith.

Stonyhurst College Observatory.

The solar work for the year consists of 233 drawings of the sun, to the scale of 10·5 inches to the diameter, taken on 230 different days, and special attention has been given to the general surface whenever the sky was favourable. The measurement of spot-area is progressing fairly. The entire chromosphere was measured on 79 days, and partially on two others; the results are published in "The Observatory." Sun-spot spectra have been examined by the Rev. A. Cortis, S.J., on ten days in 1885,

and the series of observations in preceding years is being reduced for publication.

Observations have been made of *Jupiter's* satellites, of lunar occultations, and of comets, but the weather has greatly interfered with the watch for meteors on the most important nights of the year. A list of observed meteors has been forwarded to Mr. Denning for comparison with other observations.

The *Nova Andromedæ* was examined on all fine nights, from its first appearance until it was scarcely perceptible in the 8-in. Equatorial.

The latest addition to our astronomical instruments are a Hilger solar prism, to which a Dawes eyepiece is adapted, both presented to the Observatory by I. Roberts, Esq., and a powerful direct-vision stellar spectroscope.

The upper glow continues to be watched carefully. The day-glow is never entirely absent, whilst the after-glow appears to be intermittent, or at least of varying intensity. On two occasions a recurrence of the after-glow took place some forty minutes after the first display had wholly disappeared. A glow around the moon has been not unfrequently observed.

A paper by Dr. B. Stewart has been read before the Royal Society on a comparison of the magnetograms of Kew and Stonyhurst; and copies of the photo-curves and of other magnetic results have been forwarded to Prof. W. G. Adams and to A. Schück for comparison with similar observations. The self-recording meteorological and magnetic instruments have suffered no interruption during the past twelve months.

Mr. Barclay's Observatory, Leyton, Essex.

The series of double-star observations is continued, as well as observations of the phenomena of *Jupiter's* and *Saturn's* satellites. The instruments remain the same as in former years.

The past year has been exceedingly unfavourable for astronomical observations.

Mr. Common's Observatory, Ealing.

Experiments in stellar and astronomical photography with various kinds of telescopes have been made. The De La Rue polishing machine has been removed from the University Observatory, Oxford, and erected in the workshop, and a temporary mounting and house is in the course of erection for further experiments.

A comet was found on the night of Friday, the 4th of September, and change of position noticed that evening. This proved to be a comet already found a few days before by Brooks in America. A series of observations were made on the Nova in *Andromeda* immediately after the announcement from Dun Echt.

The Earl of Crawford's Observatory, Dun Echt.

During the early part of the year 1885 micrometric observations of *Jupiter*, *Saturn*, and a few close double stars were made. In the summer considerable time was devoted to the library, the complete press-marking of which, to the number of over 15,000 volumes and pamphlets, was completed by Mr. Robert Copeland, acting as temporary librarian.

In the month of June Mr. J. G. Lohse left Dun Echt for Mr. Wigglesworth's new Observatory at Scarborough, after eight years of most zealous devotion to his varied astronomical duties at this Observatory. In the same month vol. iii. of the Observatory publications was published.

In July Dr. L. Becker, who succeeded Mr. Lohse, commenced a series of observations in the prime-vertical with a view to determining the latitude of the place as well as the differences of declination of a select list of stars. Dr. Becker has also determined the places of a variety of objects with the transit-circle in combination with direct and reflected observations of the pole star.

In the autumn and close of the year frequent observations, both spectroscopic and micrometric, were made of the "new" stars in *Andromeda* and *Orion*, chiefly by Dr. Copeland. In the first star traces of the F line are believed to have been recognised, while in the second the bright hydro-carbon bands form one of the most conspicuous spectroscopic features as seen in the Dun Echt instruments. It is confidently believed that these bright bands are to be traced with more or less certainty in all spectra of Secchi's third type. The large stellar spectroscope by Messrs. T. Cooke & Sons, mentioned in the last Report, was received in September. Although somewhat incomplete its performance was extremely satisfactory. It is expected that it can be brought into regular use by the middle of March.

In the course of the year fourteen circulars have been distributed, ten of which deal exclusively with comets. For computations of elements and ephemerides special thanks are due to Dr. H. Oppenheim of Berlin. The remaining circulars refer to the new stars and to the prediction of the Biela meteors, which were duly observed at Dun Echt. Electric illumination of apparatus with Swan lamps has been introduced with great advantage.

The daily meteorological observations and the firing of the time-gun at Greenwich noon every Saturday have been continued as in former years.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

The phenomena of the satellites of *Jupiter* and *Saturn* have been observed as in previous years. Some photometric measures have also been made with one of Prof. Pritchard's wedge photometers, made by Mr. Hilger.

The 3-ft. reflector took up much time last winter; it was set up here in the building constructed by Mr. A. A. Common, F.R.S., and tried on every suitable night. During the year several mechanical improvements, chiefly at the eye-end, have been effected. The new observatory for this telescope will, it is expected, be completed very shortly.

The Earl of Rosse's Observatory, Birr Castle, Parsonstown.

During the past year observations have been made on 87 nights. Water pressure of 60-ft. head has been applied to the driving clock of the 6-ft. reflector through the impact of a jet $\frac{1}{4}$ inch diameter, in substitution for a descending weight of 30 cwt., descending six inches per minute, and the tube, by means of an additional counterpoise, has been satisfactorily brought within the power of *one* man for raising and lowering. A speaking tube from the eyepiece to the attendant below has been added. These two alterations have enabled the telescope to be worked by two men with at least as much ease as by three before the change.

Our work has, however, been rather directed to photometry and lunar heat, without the aid of the 6-ft., than to the nebulæ. Our determinations of the heat of the moon during the eclipse of 1884, October 4, were published in the "Transactions of the Royal Dublin Society" during the year 1885. The meteorological observations have been continued as usual.

Lieut.-Colonel Tupman's Observatory, Harrow.

The meridian circle has been employed in determining the latitude and longitude of the Observatory, and in observations of the R.A. of the Moon between sunset and 13^h, 54 transits of the Moon having been obtained. The collimation, level, and azimuth errors have been determined on 80, 110, and 87 days respectively, and prove the mounting to be very stable. The equatorial intervals of the wires, the inequality of the pivots and the values of one revolution of the screws of the eyepiece micrometers have been investigated. The collimators, mounted on iron pillars out of the meridian, as described in Report last year, have been found to be not sufficiently steady. The collimation error has

always been obtained by reversing the instrument either to observe one of the collimators or over mercury. It is nearly always difficult to use the mercury trough, even when hung in rubber slings, owing to the vibrations of the soil.

The co-latitude obtained from nine stars passing near the zenith and the observed nadir points is 38° 25′ 13″·2, while from forty other stars at all zenith distances it is 38° 25′ 12″·7, the difference being probably due to division errors.

The longitude from Greenwich was found by transporting two chronometers to the establishment of Messrs. E. Dent & Co., 61 Strand, and there receiving by eye and ear the automatic signals from the mean solar standard clock of the Royal Observatory at 1^h and 2^h, and immediately taking them back to Harrow. The interval of time during which the chronometers were trusted never much exceeded three hours. This was done on six days with the following results:—

1885.	Longitude. [m. s.]
March 28	1· 19·95 West
April 13	1· 20·07
April 18	1· 19·95
May 11	1· 19·66
Aug. 26	1· 19·75
Sept. 5	1· 19·78
Mean	1· 19·86 ± ·05

Some slight improvement might be made in this determination by correcting for the difference between the error of the Greenwich sidereal standard clock found from the whole of the observations made and the error assumed when setting the mean time clock at 1 P.M. This difference, however, can hardly be of a systematic nature.

Corresponding to each of these days, complete observations for local time were obtained at Harrow on the nights immediately preceding and following the comparisons of the clocks. The rate of the Harrow transit clock is very steady. This longitude of course contains the relative personal equation between Colonel Tupman and the Greenwich standard observer; it is therefore the proper quantity to apply to Harrow time to obtain Greenwich time in the cases of occultations or transits of the Moon. Forty-five occultations of stars by the Moon have been observed, two-thirds of which have been compared with Hansen's Tables by the method employed at Greenwich.

The equatorial reflector has been chiefly used on observations of comets, generally with a ring micrometer, the instrument not yet being provided with a position circle. Owing to weakness of the declination axis, or possibly of the entire mounting, the

reflector can only be used on calm nights. A new and very much stronger declination axis is being made. Comet 1885 Barnard No. 1 was observed for place on two nights; Brooks No. 1 on four nights; Fabry eleven nights; Barnard No. 2 four nights.

The weather from the beginning of October to the end of January has been exceptionally cloudy. Only ten transits of the Moon could be obtained during those four months.

Royal Observatory, Cape of Good Hops.

The present report includes the period 1885, January 1 to December 31.

During the current observations of the preceding year it became evident that the disintegration of the inner surfaces of the crown and flint lenses of the object-glass of the Transit Circle (already considerable in 1879) was rapidly increasing. An amount of false light in the field was thus created which rendered it almost impossible to observe stars below the first magnitude by daylight. Thus the value of the observations of the sun was greatly diminished.

Observations with the Transit Circle were accordingly discontinued on February 8, and the object-glass was sent to Messrs. Troughton & Simms to be repolished. It was returned to the Cape on August 20, and immediately remounted. Observations were resumed on August 24.

Observations with the Transit Circle have thus been limited to twenty-four weeks of the year, the total work being as follows:—

Number of determinations of collimation	22
„ „ level	156
„ „ Nadir Point	126
„ „ runs	127
„ „ horizontal flexure	15

	Direct.	Reflex.
Number of observations of stars in R.A. ...	1401	243
„ „ „ N.P.D. ...	918	261

	Direct.	Reflex
Observations of both limbs of Sun in both elements	21	12
Observations of Mercury in both elements ...	13	7
„ Venus „ ...	18	10

Advantage was taken of the necessary repolishing of the object-glass to have new steel screws (in lieu of the worn bronze screws) fitted to the microscopes of the Transit Circle. At the same time the order of the numbering of the graduations of the

drums of three of the microscopes was reversed, so that these microscopes might be turned 180°. Thus (as now at Greenwich) the wear of the screws produced opposite effects in the readings of each alternate microscope. The investigation of the new screws, although not yet complete, proves that their errors are very small.

Whilst the Transit Circle was idle one of the portable Transits by Troughton & Simms of 3 inches aperture was employed partly in an independent determination of the Right Ascensions of certain zones of stars for comparison with the results of the Transit Circle, and partly in exchanging telegraphic signals with Capt. Morris, R.E. (in charge of the field work), for determination of the astronomical longitude of points on the Geodetic Survey of South Africa, and in comparison of the personal equation of the observers with that of Capt. Morris.

For these purposes there have been made with the 3-inch Transit—

Determinations of collimation and level	304
Transits of stars	2433

Much time and labour have been bestowed upon perfecting the working and studying the constants of the Great Indian Theodolite. The investigation of the Pivot Errors from the construction of the instrument has presented great difficulties, but these have now been overcome, although the work is not yet quite complete.*

The errors of the screws (in some cases considerable) are fully investigated, and the corrections tabulated. From the fact that a different zero of the Horizontal Circle is employed on each night of observation it is not yet determined whether it will be necessary to completely investigate the errors of its graduation.

* The comparatively small diameter of the pivots (about 1 inch) does not permit the employment of the axis as a revolving collimator, according to Airy's elegant method. The utmost efforts of Mr. Simms did not succeed in engraving a perfect dot, at least one whose image would be beyond suspicion of change in its apparent centre, whilst its co-ordinates are measured at symmetrically arranged readings of the vertical circle. (An error of eccentricity in the position of the dot is of no consequence so long as the errors of the screw of the watch microscope are known or eliminated.) Such errors were partly, or perhaps completely, eliminated by reversing the dot-holder 180° between alternate sets of measures, but there remained some uncertainty which it was considered desirable to remove. Acting on a suggestion of Captain Morris, the experiment was made of grinding a particle of mercury in a drop of Canada balsam dissolved in ether, between two sheets of thin glass, such as that employed for covering microscope slides. In this way the mercury is subdivided into minute and exquisitely perfect spherical globules, which become firmly cemented between the glass plates when the Canada balsam has set. The small double plate of glass is then cemented on the end of the pivot and illuminated through the perforation of the pivot opposite to the watch microscope, and it becomes easy to find a perfect dot near the axis of rotation.

The values and inequalities of the two delicate ether levels, by which the inclination of the horizontal axis is determined, have been investigated. It was also found that the levelling of the instrument was very imperfect, the zero of the frame levels being different to the extent of several seconds of arc, according to the direction of rotation. This discordance was traced to imperfect fitting of the revolving part on the lower flange of the fixed vertical cone. The bearings were re-ground by Mr. Gill, and finally a perfect fit and perfect results in levelling were obtained after a fortnight's labour. It is noteworthy, however, that when observations are made in reverse positions of the instrument, the resulting azimuth is free from errors due to this cause if the levels are read simultaneously with (*i.e.* immediately before and after) the observation in each position. The only inconvenience is the increased difficulty of determining the level zero.

At first there was some instability in the relative azimuths of the meridian marks (in focus of and 150 ft. distant from lenses to N. and S. of the instrument), probably because the foundations of the four recently built piers had not had sufficient time to settle. For the last three months, however, the relative azimuth of N. S. mark has not changed half a second of arc.

Secondary batteries have been employed with great success for the incandescent lamps which illuminate the circle microscopes and the field of view. These batteries are charged once or twice a week by six Grove cells arranged in series of three. It is impossible to over-estimate the advantage of this method of illumination; its perfect freedom from flickering in the highest wind, its perfect constancy, perfect control, perfect cleanliness, and the comparatively small amount of heat given off, combine to increase the accuracy and ease of working in a manner that can only be fully appreciated by trial.

The complete working out of all details, the preparation of working forms, selection of stars and necessary preliminary computations, delayed commencement of definitive observations till September 1. Since that date the following observations have been made:—

Number of observations of meridian marks	129
Number of azimuths of circumpolar stars at elongation ...	210
Number of azimuths of northern stars for latitude by Kapteyn's method	63

The results appear to be very satisfactory.

A fundamental latitude is being determined by Prof. Kapteyn's method ("Copernicus," vol. iii. p. 147). The declinations of circumpolar stars are determined by observing azimuths of greatest elongation. Declinations of northern stars will be determined by connecting them by Talcott's method with

those of southern stars determined as above. In this way it is hoped that a new and trustworthy system of fundamental declinations, entirely independent of refraction, will be established.

Comet 1884 Wolf has been observed on eleven nights between January 7 and February 14; and Comet 1885 Barnard on six nights between July 12 and August 3.

An unsuccessful search was made for Biela's Comet after the meteoric shower of November 27; but the weather in the early mornings was cloudy for a week after that date, so that the most favourable opportunity was lost.

The observations of Comets Pons-Brooke, Barnard, and Wolf, made in 1884, have been communicated to the *Monthly Notices* and the *Astronomische Nachrichten*. The places of comparison stars for Comet I. 1881, which were observed at the request of Dr. E. von Rebeur have been communicated to the *Astronomische Nachrichten*.

A paper containing the results of observations of the Great Comet of 1882, with drawings of the nucleus and photographs of the comet, has been prepared. The sheets have been passed through the press by Mr. Finlay during his leave of absence in England, and will probably be ready for distribution before this report is published.

The results of observations of stars with the Transit Circle from 1879 till the repolishing of the object-glass are being formed into a catalogue for the Equinox, 1885. A working list for a new catalogue (Epoch 1890), containing 2,500 stars, has been prepared. It is intended that the observations for the new catalogue shall extend over ten years, and one of its principal objects will be to connect the system of declinations determined with the Great Theodolite and the equal altitude instrument, with the systems of the various Ephemerides.

Aided by a vote of 300*l.* from the Government Grant Fund of the Royal Society, the services of Mr. C. Ray Woods have been secured as photographic assistant.

The objects which induced H.M. Astronomer to apply for this aid were—

1. The desirability of securing, as soon as possible, a *Durchmusterung* of the southern heavens, since the photographs of the Great Comet of 1882 obtained at the Cape had proved the practical possibility of doing this work by direct photography from the sky.
2. The method of Dr. Huggins for photographing the Corona without an eclipse appeared to offer a new and interesting field of study.

The first of these objects has made very satisfactory progress. Mr. Dallmeyer had most generously lent one of his beautiful rapid rectilinear combinations, composed of two concavo-convex achromatic combinations of 6 inches aperture. This was

mounted in a strong square wooden tube attached to the declination axis of a powerful equatorial stand belonging to H.M. Astronomer (the stand of his Heliometer). A telescope of $3\frac{1}{2}$ inches aperture and 45 inches focal length is used as a guiding telescope.

Mr. Woods reached the Cape on February 19; the star photographs were begun on April 2. The following amount of work has been secured:—

	No. of Plates.
Perfectly successful plates (exposed an hour in clear sky) ...	209
Interrupted by clouds shortly before an hour's exposure, or otherwise slightly defective, but still useful	41
Lost by cloud or chemical faults	35
	285

Each plate is 6 inches square, covering an area of about 36°. A large overlap is provided for, and every area is photographed twice, so as to render it impossible to confound the images of faint stars with minute dust-specks. In this way the whole sky, from declination 63° to 90°, has been photographed in duplicate, excepting the area from R.A. 5^h to 8^h, which latter will be completed before the end of February, besides a considerable portion of the next zone. The zones are 5° apart.

From similar photographs taken near the equator and compared with Argelander's *Durchmusterung* it is evident that these plates show all stars to $9\frac{1}{2}$ magnitude.

Steps for commencement of the measurement, reduction, and cataloguing the work are under consideration.

In order to obtain without additional labour (beyond that of development of the exposed plates) pictures showing stars of 12th and 13th magnitude, for discussion of the distribution of stars according to magnitude, and also for the photographing of special areas such as those of dense clusters, it was desirable to obtain a more powerful optical apparatus.

On mentioning the matter to Mr. James Nasmyth, he most generously placed the funds necessary for purchase of a "Nasmyth lens" in the hands of Dr. Huggins, by whom a specially corrected photographic objective of 9 inches aperture and 9 feet focal length was ordered from Mr. Grubb. Plans for the mounting of this lens, together with a powerful guiding telescope and an improved Dallmeyer apparatus, have been prepared by H.M. Astronomer, and are under construction by Mr. Grubb.

The field of the Nasmyth lens will be much more limited than that of Dallmeyer's apparatus, but one should obtain from it by simultaneous exposure a photograph of all stars to the 12th or 13th magnitude within a radius of 1° or $1\frac{1}{2}$° of the centre of each *Durchmusterung* picture, and this will afford sufficient data for any general discussion of star distribution.

On account of delays from transhipment and other accidents the Coronograph did not reach the Cape till the end of June.

Many alterations had to be made to remove instrumental defects, so that the first of the series of pictures was not obtained till July 20.

There seems little doubt that true pictures of the Corona have been obtained, but H.M. Astronomer prefers to defer expression of a definite opinion till the apparent changes which he believes to have noted have been confirmed beyond doubt. Meanwhile the pictures have been sent to England, and a series of drawings is being prepared from them by Mr. Wesley.

An active correspondence has been maintained with Messrs. Repsold, of Hamburg, in reference to details of the new Heliometer.

The new Record Room (forming the foundation of the Heliometer Observatory) has been completed with the exception of some internal fittings.

The framework of the new observatory should reach the Cape before the middle of 1886, and the whole be fitted up ready for the reception of the new Heliometer, before the end of that year.

The Geodetic Survey of South Africa makes rapid progress.

An arc of latitude $3\frac{1}{2}°$ in length has been completed in Natal; it includes astronomical latitudes and azimuths at three points, and three astronomical longitudes determined by exchange of signals with the Cape Observatory. Each longitude rests on exchanges on at least four nights, with time determinations at both ends. Captain Morris after these operations compared personal equation with the Cape observers on eight nights. The stars employed in the Talcott latitude observations are all included in the Cape observing list. Rapid progress is being made in extension of the triangles from Natal through Griqualand East to Port Elizabeth.

The absence in England, first of Mr. Pett, and afterwards of Mr. Finlay, on well-earned holiday, together with a large variety of work requiring his close personal attention, have prevented so much progress being made by H.M. Astronomer in the reduction of the Victoria and Sappho observations as would otherwise have been the case. It is expected, however, that the work will be completed during 1886.

During the present financial depression at the Cape it has not been considered desirable to press for funds for reduction of the Tidal Observations; the Admiralty has decided that the cost properly lies with the Colony.

The meteorological observations made in the year 1884 at the Observatory, together with those taken in different parts of the Colony, have been printed in the Reports of the Cape Meteorological Commission.

Hong Kong Observatory.

The new time-ball was dropped daily at 1 p.m. since January 1, 1885—Sundays and holidays excepted, as well as some days on which severe thunderstorms interfered. During a portion of September the time-service was interrupted, owing to fever among the staff. The ball is dropped automatically by the mean-time clock, which is electrically set to correct time by comparison with the sidereal standard clock, by aid of which also chronometers are rated. The errors of this clock have been tabulated and discussed up to date, and the temperature coefficient has been determined.

Transits of time stars and of some stars of southern declination, as well as of *Polaris* (for determination of the azimuth) and of the moon, were observed, and with the Lee Equatorial phenomena of *Jupiter's* satellites and a few micrometric measures were secured. The *Andromedes* were observed on November 27.

Absolute magnetic observations were made monthly, but the automatic tide-gauge has not yet been mounted and worked for want of funds.

The self-recording meteorological instruments were continuously marked, and the readings tabulated. Daily weather reports based on telegraphic information and storm warnings were issued. The complete monthly reports are published up to September inclusive. In these reports the observations made at the high-level station on Victoria Peak are also published.

Meteorological instruments of approved pattern have been verified and forwarded to the treaty ports and lighthouses in China, and the observers have been instructed. Their observations have not been reduced and discussed for want of funds, but have, in connection with abstracts of ships' logs, enabled complete investigations of typhoons to be carried out.

The first annual volume was published early last summer.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Discovery of Minor Planets.

The following nine minor planets were discovered in the year 1885:—

No.	Name of Planet.	Date of Discovery, 1885.	Discoverer.	Place of Discovery.
245	Vera	Feb. 6	Pogson	Madras
246	Asporina	Mar. 6	Borrelly	Marseilles
247	Eukrate	Mar. 14	Luther	Düsseldorf
248	Lameia	June 5	Palisa	Vienna
249	Ilse	Aug. 16	Peters	Clinton
250	Bettina	Sept. 3	Palisa	Vienna
251	Sophia	Oct. 4	,,	,,
252	Clementina	Oct. 27	Perrotin	Nice
253		Nov. 12	Palisa	Vienna

Minor planet No. 244, discovered by Herr Palisa on October 14, 1884, has been named *Sita*.

The Comets of 1885.

Six comets have been discovered during the year 1885, including the periodical comet of Tuttle. These are noticed in order of discovery.

I. A comet discovered by Mr. Barnard, of Nashville, on July 9, presenting a circular appearance of about one minute in diameter, and as faint or fainter than a star of the 11th magnitude. At the time of discovery the comet was south of the Equator and moving southwards. Predicted positions, computed from elements derived by Dr. Lamp, were telegraphed to the southern observatories, where the comet, growing gradually fainter, was seen up to August 15. The orbit does not differ sensibly from a parabola, but the elements are remarkable, since they exhibit a perihelion distance greater than that of any other comet with the exception of that of 1729.

II. A suspicious object was seen on August 31 by Mr. Brooks, of Phelps, N.Y., which on September 2 proved to be a comet. This appears to have been independently discovered by Mr. Common at Ealing on September 4. The appearance was that of an ordinary telescopic comet with some central condensation. This comet had passed its perihelion passage some three weeks before its discovery, and was gradually growing fainter, and since its path was well represented by parabolic elements the comet possessed but little interest. The best elements appear to be those due to Dr. Oppenheim.

III. The periodical comet of Tuttle, which seems to have been systematically sought for and continuously observed only at the observatory at Nice. The perturbations of this interesting comet of fourteen years' period, and the preparation of an ephemeris for its approaching apparition, were undertaken by Dr. Rahts, of Königsberg; but unfortunately the circumstances of its return were not favourable to observation, and it is fortunate that MM. Charlois and Perrotin have succeeded in making a series of observations, though it extends only from August 8 to August 22. M. Perrotin reports that the observation of the comet presents great difficulty, owing to the feebleness of its light and its small altitude above the horizon during the ten or fifteen minutes before sunrise, during which alone the observation is possible. Professor Lewis Swift speaks of the comet as fairly bright in a dark sky, but his observations of the place have not yet been published. Theoretically, the comet had about one-third the brilliancy it possessed when first observed on its previous return in 1871. The observations of MM. Charlois and Perrotin show that the predicted place was in error by about $12^s{\cdot}6$ in R.A. and $5'\ 36''$ in declination, which discrepancies between the observed and computed place could be satisfactorily removed by corrections to the mean anomaly and mean motion of $42''$ and $0''{\cdot}00852$ respectively. This agreement is very satisfactory, as establishing the correctness of the mean motion in the elements derived by Dr. Rahts from the 1858 and 1871 observations, as well as of the effects of the perturbations in the interval 1871–1885, the publication of the complete discussion of which was delayed till after the observation of the comet.

IV. Discovered by M. Fabry, of the Paris Observatory, and originally reported as a faint object with nucleus, but subsequently described as a tolerably bright object, with well-pronounced stellar nucleus of the brightness of a star of the 11th magnitude. The perihelion passage does not occur till next April, and the determination of the elements by the method of Olbers is not unaccompanied

with difficulty. The best elements at this date are probably those of Dr. Oppenheim, which embrace twenty-five days' observation; but he reports that an error in the determination of the ratio of the curtate distances at the first and third observation occasions nearly three and five times the same error in the radii vectores of the comet at the same dates respectively, the middle observation being at the same time fairly well represented.

V. A comet discovered by Mr. Barnard, of Nashville, on December 3, and described as tolerably bright, but somewhat fainter than that of Fabry. The elements are not yet determined with precision, but the approximate orbit has great resemblance to that of the second comet of 1785. Dr. Hepperger has given elliptical elements with a period of 101·1 years, but the deviations of the path from either the ellipse or the parabola are not yet sufficient to decide the question of identity. As in the comet of Fabry, the orbit is nearly perpendicular to the ecliptic, and its discovery precedes its perihelion passage by some months.

VI. On December 26 Mr. Brooks, of Nashville, discovered another comet, which, however, is scarcely likely to prove interesting, since the comet at the time of its discovery was moving away from both the Sun and the Earth, and the elements do not coincide with those of any comet previously computed nor show signs of any ellipticity.

In addition to these observations, it may be as well to remark that Tempel's comet (1867, II.) approached the Earth last spring (being its fourth appulse since its elliptic character became known) without being detected. The position in the sky was not favourable for observation, and the continued perturbations of *Jupiter*, which in this comet may be excessive, have, on the whole, tended to make its observation more and more difficult. M. Gautier has discussed its path with apparently great care (the details are not yet published), and has given osculating elements for April, 1885, which show that a diminished excentricity has been accompanied by an increased axis major, and that the passage through the perihelion has been delayed no less than 148 days.

A comparison between the elements of the comet in 1867 and those computed by M. Gautier for its appearance in 1885 well illustrates the difficulty of deciding on the identity of two comets, simply by a comparison of their orbits derived from the observations during the time of the comet's visibility.

Another fact to which it seems desirable to call attention is the return of Olbers' comet, for which Dr. F. K. Ginzel has prepared extensive sweeping ephemerides. The most probable date for its return is December 17, 1886, but since the uncer-

tainty in this date amounts to ± 1·6 years, systematic searching for the comet is now desirable.

Dr. Galle has published in the *Astronomische Nachrichten* a catalogue of the orbits of recently-observed comets, as well as of those which have been improved by the more careful discussion of ancient observations. This is likely to prove a valuable and welcome contribution to cometary literature. The catalogue is really a continuation of that given in the third edition of Olbers's *Methode zur Berechnung der Cometenbahnen* (1864), apparently prepared, or at least now published, at the express solicitation of the editor of the *Astronomische Nachrichten*. It commences, however, in 1860, and in an approximate form gives the most accurate orbit of each comet that has appeared within the quarter of a century ending in 1884, together with the period of visibility and the length of time over which the observations employed in deriving the elements extend. From this list a computer can easily see what orbits have been definitely determined, and of what comets further discussion is likely to be useful. In the accompanying notes are short descriptions of and references to the original authorities where comets have been observed, but not a sufficient number of times to enable the elements to be determined.

It is statistically interesting to notice that the number of comets for which orbits have actually been computed up to the end of 1884 is 302, and of these twelve have proved themselves periodic, and have actually been re-observed more or less frequently at subsequent returns. Taking these into account, the number of computed orbits occasioned by cometary discoveries is 357. In the quarter of a century under immediate consideration 94 have been computed, while the number of improved orbits is 42. W. E. P.

Mr. G. W. Hill on the Lunar Inequalities due to the Ellipticity of the Earth.

It is well known that M. Delaunay was unfortunately prevented by a premature death from completely carrying out his purpose of determining all the sensible inequalities of the Moon's motion by means of his very original and beautiful method of treating that subject. Happily the two magnificent volumes in which he determines the inequalities which are caused by the disturbing force of the Sun, on the supposition that the motion of the Earth about the Sun is purely elliptic, are complete in themselves. The small effects due to the action of the planets and the spheroidal figure of the Earth, as well as those which arise from the disturbances of the Earth's motion, remained to be determined.

Mr. G. W. Hill, who is already well known for his skilful treatment of special portions of the lunar theory, has, in the

paper now to be noticed, produced a valuable supplement to Delaunay's work by applying the same method to the determination of the lunar inequalities which are due to the ellipticity of the Earth. This paper forms part ii of vol. iii. of the valuable series of astronomical papers prepared for the use of the *American Ephemeris* and *Nautical Almanac*.

The author first develops the terms of the disturbing function which are introduced by the ellipticity of the Earth, by substituting for the Moon's coordinates their disturbed values as already given by Delaunay's work. Some idea of the length and complexity of this substitution may be formed when it is stated that the development so obtained contains one constant term accompanied by 121 periodic terms.

The next process is by a series of transformations of the variables involved gradually to remove these periodic terms from the disturbing function, so that it is at length reduced to the form of a constant term.

The number of such operations required to effect this reduction amounts to 103, although each operation is individually sufficiently simple.

By the essential principle of Delaunay's method the differential equations throughout these transformations always preserve their canonical form, and therefore when the disturbing function has been reduced to the above-mentioned simple form, the integrals are at once obtained.

In the next place the transformations indicated in the 103 operations above mentioned are also made in Delaunay's expressions for the three coordinates of the Moon, so that finally the values of these coordinates are found in terms of three arbitrary constants and three angles, each of which consists of a term proportional to the time joined to an arbitrary constant.

The coordinates thus expressed are the longitude, the latitude, and the reciprocal of the radius vector. As this last quantity is only intended to be employed in finding the Moon's parallax, it is given by Delaunay with much less precision than the other two coordinates, a circumstance which is to be regretted as an imperfection from a theoretical point of view.

The expressions thus found are purely analytical, that is the coefficients are expressed in series of powers and products of Delaunay's constants m, e, e', γ, each term also involving as a factor a constant quantity which depends on the figure of the Earth.

In order to make his work more complete, Mr. Hill determines the numerical value of this last-mentioned factor by a very elaborate discussion of the results of numerous pendulum expements.

Finally, by the substitution of the known values of the constants employed, the numerical expressions for the perturbations of the Moon's coordinates produced by the figure of the Earth are obtained.

It may be remarked that comparatively few of the coefficients so found amount to an appreciable quantity, by far the larger number being utterly insensible.

The quantity m denoting, as in Delaunay, the ratio of the mean motion of the Moon to that of the Sun, it is found that the analytical expressions of most of the coefficients involve negative powers of m. This circumstance, which never happens in the case of the perturbations due to the Sun's action, has given rise to a difficulty in some minds as to the admissibility of Mr. Hill's results. Mr. Stockwell, in particular, in an article in the twenty-ninth volume of the *American Journal of Science*, asserts that the value given to the coefficient of the principal equation of latitude leads to a manifest absurdity, and "justifies the suspicion that the entire solution is erroneous."

The difficulty thus noticed by Mr. Stockwell, however, admits of an easy explanation. He applies Mr. Hill's formulæ to a case in which they are not applicable, and for which they were not intended. The form of development in series adopted by Mr. Hill is founded on the supposition that the perturbations due to the Earth's figure which he wishes to determine are very small compared with those due to the action of the Sun, and therefore he expressly neglects quantities which are proportional to the square of the first-named perturbations. Now, in the case of our Moon, which is that treated by Mr. Hill, the above-mentioned supposition certainly holds good, and consequently his formulæ are sufficiently accurate.

If, however, the Sun's distance from the Earth were very much greater than it is, or if the Moon's distance were very much less than it actually is, then the perturbations arising from the Earth's figure might be much greater than those which arise from the Sun's action, and a different form of development would have to be adopted.

In this latter case it would be better to refer the motion of the Moon, not to the ecliptic, but to a fundamental plane passing through the line of intersection of the equator and ecliptic, and occupying a definite intermediate position between those two planes. If the perturbations due to the action of the Sun are much greater than those due to the Earth's figure, this fundamental plane nearly coincides with the ecliptic, whereas if the latter perturbations are much greater than the former, the fundamental plane nearly coincides with the equator. In Mr. Hill's formula, the principal term in the expression for the latitude nearly represents the distance of the fundamental plane from the ecliptic corresponding to the actual longitude of the Moon at any time.

A simple analytical illustration of the change of form of the coefficient of this term of the latitude in different circumstances may be given.

If m have its usual meaning as before stated, and if c be a small positive constant depending on the ellipticity of the Earth,

then the value of the coefficient in question is approximately proportional to

$$\frac{c}{m^2+c}$$

Now if, as in the case of our Moon, c is very much smaller than m^2, so that we may neglect the square of c compared with that of m^2, the quantity just mentioned becomes approximately $= \frac{c}{m^2}$; whereas if m^2 is small compared with c, the same quantity becomes nearly $= 1$, and the co-efficient becomes nearly independent of the ellipticity of the Earth, as it should do, since in this case the coefficient of this term is approximately equal to the sine of the obliquity of the ecliptic.

Mr. Stockwell's second objection, that Mr. Hill has omitted to take into account the modification of the Sun's disturbing force which is caused by the alterations of the Moon's coordinates due to the ellipticity of the Earth, seems to arise from a misapprehension on his part of the spirit of Delaunay's method. These alterations of the Moon's coordinates are implicitly involved in the variables a, e, γ, l, g, h, throughout the series of operations by which Delaunay gradually removes from R the periodic terms arising from the action of the Sun.

Professor Asaph Hall's Researches on the Orbits of Satellites.

In Appendix I. to vol. xxviii. of the "Washington Observations" Professor Asaph Hall discusses the observations of *Oberon* and *Titania*, the two outer satellites of *Uranus*, made by himself with the great 26-inch refractor of the Washington Observatory during the years 1875, 1876, and 1881–1884.

The apparent position of the orbits was then suitable for a good determination of the node and inclination, and the main results of this discussion are what appear to be very accurate values of these elements, and of the apparent mean distances of the satellites, and consequently a trustworthy value of the mass of *Uranus*.

If N denote the place of the node, and J the inclination of the orbits on the equator of 1883, the values found for these elements are—

$$N = 165^\circ 8$$
$$J = 75^\circ 3$$

Also the mass of *Uranus* $= \frac{1}{22682}$, that of the Sun being unity.

The author thinks that this value of the mass is smaller than any found before, but it may be remarked that a still smaller

value, viz. $\frac{1}{24605}$, was found many years ago by Professor Lamont, of Munich.

Appendix II. to the same volume of the "Washington Observations" contains a similar discussion of the observations of the satellite of *Neptune*, made with the great Washington refractor by Professor Hall himself in the years 1875–1877 and in 1881–1884, and by Professor Holden in the years 1874–1878, and also the observations made at Malta by Messrs. Lassell and Marth in the years 1863 and 1864.

The resulting place of the node and the inclination of the orbit to the equator of 1883 are—

$$N = 184^{\circ}3$$
$$J = 120^{\circ}0$$

Also the mass of *Neptune* resulting from the observations of Lassell and Marth is $\frac{1}{17850}$, whilst that which results from Professor Holden's observations is $\frac{1}{18279}$, and that from Professor Hall's own observations is $\frac{1}{19092}$, that of the Sun being 1.

Appendix I. to the "Washington Observations" for 1882 contains an elaborate investigation of the orbit of *Japetus*, the outer satellite of *Saturn*, also by Professor Hall. The observations employed were made with the great Washington refractor. The observations consisted partly of measurements of differences of right ascension and declination of *Japetus* and the planet, and partly of measurements of angle of position and distance, made by Professor Hall himself between the years 1875 and 1884, and likewise included similar observations made by Professor Newcomb in 1874.

These observations are compared with the elements of the orbit given by M. Tisserand in the first volume of the Annals of the Observatory of Toulouse, and equations of condition for the correction of the elements are formed from them and then solved in the usual way. The periodic time is corrected by comparing these observations with one made by Sir W. Herschel in 1789, and with the observations of Sir John Herschel at the Cape of Good Hope in 1837.

Professor Hall then proceeds to calculate the principal perturbations of *Japetus* which are due to the action of the Sun, confining his attention to the secular perturbations, and to such periodical perturbations as are independent of the position of the satellite in its orbit.

He also calculates the value of an inequality of long period in the motion of *Japetus* caused by the action of *Titan*, the exist-

ence of which was pointed out by Plana, and which arises from the fact that five periods of *Titan* are nearly equal to one of *Japetus*.

The following are the elements of the satellite's orbit which result from the observed differences of right ascension and declination in the oppositions of 1875, 1876, and 1877 :—

Epoch 1876, Sept. 20·5, Greenwich Mean Time.

Mean Longitude	E = 7° 35′ 9″·8	Referred to the ecliptic and the mean equinox, 1876·0.
Perisaturnium	P = 349 59 27·8	
Longitude of node	n = 142 30 11·7	
Inclination	i = 18 35 41·1	

Apparent mean distance a = 515″·523

Eccentricity e = 0·02843

The following are the elements found from the angles of position and the distances observed from 1876 to 1884.

Epoch 1880, March 17·0, Greenwich Mean Time.

E = 26° 43′ 2″·0	Referred to ecliptic and mean equinox, 1880·0.
P = 353 46 48·2	
n = 142 34 23·6	
i = 18 33 2·3	

a = 515″·512

e = 0·02722

Prof. Hall reduces these elements to the mean elliptic elements for 1876 and 1880, by deducting the periodical perturbations due to the Sun's action which he has calculated, and he also gives the numerical values of the secular perturbations of the elements due to the same cause; but since the secular perturbations due to the figure of the planet are very uncertain, while those due to the action of the Ring and of the other satellites are altogether unknown, the actual secular perturbations can only be determined by future observations.

The periodic time of *Japetus* is found to be 79·3310152 mean solar days.

Prof. Hall deduces the following value of the mass of *Saturn*, viz. $\frac{1}{3481\cdot3}$, that of the Sun being unity. This is slightly greater than that determined by Bessel, $\frac{1}{3501\cdot6}$, which is usually employed.

Finally he gives some tables which facilitate the calculation of elliptic places of the satellite.

Prof. H. G. van de Sande Bakhuyzen on the Rotation Period of Mars.

Professor H. G. van de Sande Bakhuyzen gives in a memoir now published separately, but which will form part of the seventh volume of the "Annals of the Leiden Observatory" a fresh discussion of the rotation period of *Mars*. An opportunity for such an investigation had been afforded by the acquisition in 1876 by the University of Leiden of the papers and drawings prepared by Schroeter for his projected great work on *Mars*. These were published, under Prof. Bakhuyzen's editorship, in 1881. In addition to the valuable observations thus placed at his disposal, Prof. Bakhuyzen was in the possession of considerably more material than had been in the hands of Kaiser, Proctor, or Schmidt, when they were engaged on the same discussion, since *Mars* was well and frequently observed both in 1877 and 1879.

The author's method of using his material has been as follows. Confining himself at first to a consideration of the drawings made during the oppositions of 1862 and 1864 by Kaiser, Lockyer, Lord Rosse, and Dawes, and adopting Schiaparelli's position—unquestionably very correct—for the north pole of *Mars*, he has ascertained the position of his assumed zero-meridian for the beginning of 1863, and found that it coincided with the Martial meridian passing through the Earth's north pole, on January 1, 1863, at $20^h\ 27^m\cdot0 \pm 4^m\cdot0$ Berlin M. T. The meridian adopted for the zero of longitude is very close to that selected by Schiaparelli, and lies 2° to the east of Mädler's point *a*. The next step was with Proctor's value for the rotation period—the one he published in 1869, viz., $24^h\ 37^m\ 22^s\cdot74$—to compute the areographic longitude for the centre of the disc for a number of dates for which we possess drawings of the planet. The drawings employed have been those of Huyghens for 1659, 1672, and 1683, of Hooke for 1666, Herschel 1777 to 1783, Schroeter 1785 to 1802, Beer and Mädler 1830, Schiaparelli, Lohse, Green, Niesten, and Dreyer 1877, and Schiaparelli 1879, besides those already mentioned for the oppositions of 1862 and 1864. The longitudes of a number of the most conspicuous spots were then determined; and from a comparison of these longitudes, a correction to the assumed rotation period has been derived, the resulting corrected period being $24^h\ 37^m\ 22^s\cdot66 \pm 0^s\cdot0132$, or $0^s\cdot08$ less than the one adopted from Proctor. It seems clear that this new value, which is very nearly the mean of the best previous determinations, is an improvement even on the very close approximations we possessed before.

Prof. Bakhuyzen adds a brief note on probable changes on the surface of *Mars*. He considers that it is highly probable that "Huggins Inlet," or the "Cyclopum" canal in Schia-

parelli's nomenclature, and perhaps Schiaparelli's canal "Læstrygonum" were much more conspicuous objects at the time when Schroeter made his observations than they have been during recent oppositions. The evidence with regard to the "Cyclopum" canal certainly appears very strong.

A table for inferring the time of coincidence of Prof. Bakhuyzen's adopted zero-meridian with the Martial meridian passing through the north pole of the earth for any date during the present century, and another giving the angular rotation-motion of *Mars* corresponding to any number of hours or minutes, conclude the memoir. E. W. M.

The Cape Catalogue for 1850.

A catalogue containing the places of 4,810 stars for the epoch 1850 has been published by Dr. Gill. It contains the results of observations made at the Cape Observatory during the years 1849-52, under the superintendence of the late Sir T. Maclear. The R.A.'s were all observed with Dollond's transit of 5 inches aperture, which was mounted by Fallows in 1828. The N.P.D. observations were made with Jones's 6-foot mural circle, with 4-inch object-glass, erected in 1839. The stars whose places are given in this catalogue are stars of the British Association Catalogue south of the equator. Apart from some discussions arising from attempts to reconcile the observations of Lacaille and others with the results obtained at the Cape (published in the *Memoirs*, vol. xx.), the reductions were left in a very incomplete state until they were taken up by Mr. Stone, who pushed them on as opportunity offered during his years of office at the Cape, about half of the reductions to mean place having been made under his direction. The clock errors used in the reduction of the R.A. observations were obtained from observation of *Nautical Almanac* stars. Certain corrections have been applied to the N.A. places of these stars, taken from a table prepared by Mr. Stone. This table is printed in the introduction to the catalogue. In the N.P.D. observations two microscopes only were as a rule employed, and there does not appear to have been any investigation of the errors of division. Dr. Gill, however, has drawn up a table of corrections, which approximately reduce the mean of two microscopes to the mean of six. The latitude adopted was $-33° 56' 3''\cdot5$, and the refractions used were those of Bessel's Tabulæ Regiomontanæ. The index error of the exterior thermometer was assumed to be insensible, but strictly a correction of $-0°\cdot27$ Fah. should have been applied. No corrections have been applied for flexure. No proper motions are given in the catalogue, and none have been applied to the star places. The corrections to mean place for the greater number of observations were computed with the aid of Mr. Stone's tables.

For the purpose of determining the systematic errors of this

catalogue, Dr. Gill has compared it with the Cape Catalogue for 1880. The separate results of the comparison for each star are given in the body of the work, the collected results being printed in the Introduction.* When proper motions are given by Mr. Stone in the 1880 catalogue, allowance for such has been made in the comparison; otherwise it is assumed that the accidental effect of proper motion will disappear from the mean of so large a number of stars, some 3400 in all. From this comparison it appears that the agreement in N.P.D. is not unsatisfactory, there being a practically uniform difference (within the limits of error of most of the separate N.P.D.'s) between the catalogues through the range of polar distance over which the observations extend. But the comparison in right ascension is by no means so satisfactory, as there are considerable discordances depending not only on R.A., but also on polar distance, which Dr. Gill appears to think may possibly arise from the non-reversible character of the Cape transit-circle, with which the observations contained in the 1880 catalogue were made, as in his opinion it is possible either that the collimation of the instrument may not remain constant at different altitudes, or, less probably, that the observations may be effected by lateral refraction caused by the non-symmetrical position of the wings of the building with respect to the instruments. At all events, Dr. Gill considers that there is more marked difference depending on N.P.D. between the R.A.'s of the Cape and Greenwich Catalogues for 1860, when non-reversible instruments were employed, than in the 1840 catalogues, when reversible transits were used at both Observatories. And a comparison of the R.A.'s of the Cape and Greenwich Catalogues for 1850 appears to Dr. Gill to bring additional evidence to show that the R.A.'s of the Cape Catalogue for 1850 may be accepted with considerable confidence. On the whole, however, Dr. Gill is inclined to think that the declinations of the catalogue must be considered superior to the right ascensions. The observations in R.A. have given a great deal of trouble; the work of one observer had to be entirely rejected, and that of another proved in some instances to be so bad that occasionally a whole night's observations have had to be rejected also. This naturally throws a certain amount of doubt on the accuracy of the right ascensions of the 1850 catalogue, and it is therefore not surprising to find that some astronomers have not been able to accept Dr. Gill's conclusions as to the results derivable from the comparison of the 1850 and 1880 catalogues. In the discussions which have

* There appear to be some numerical *errata* in the table on page xiv of the Introduction giving the comparison of the catalogues in N.P.D. arranged in groups of 4^h in R.A and 12° in N.P.D. The mean for the zone 138°–150° of N.P.D. should be +0″·70 instead of +0″·87, and the number of stars 666 instead of 535. The mean for the group 8^{hs}–12^{hs} of R.A., should be +0″·24 instead of +0″·30, and the number of stars 639 instead of 508. The general mean should be +0″·45 instead of +0″·46, and the number of stars 3535 instead of 3404.

been published on the subject two points have chiefly been dwelt upon: (1) that from our ignorance of the proper motions of southern stars it is impossible to compare catalogues whose epochs differ by as much as twenty-five years, so as to deduce any reliable results with regard to their systematic errors; and (2) that even if no considerable error is introduced from this cause, when such a large number of stars are used in the comparison, there is evidence, derived from comparisons with other southern catalogues, to show that the R.A.'s of the 1880 catalogue are probably superior to those of the 1850 catalogue. It would appear, therefore, that the discordances pointed out by Dr. Gill are not necessarily due to the causes which have been mentioned by him. In order to throw additional light on this subject, Dr. Gill proposes to observe a series of stars nearly simultaneously both with the transit instrument and the transit-circle, and points out that much interest will attach to a comparison of Mr. Stone's extensive catalogue with the great Cordoba Catalogue, in the observations for which Dr. Gould has employed a reversible transit-circle.

Apart from the discussion to which its publication has given rise, the Cape Catalogue for 1850 is a welcome addition to the published record of work done at the Cape Observatory.

Uranometria Nova Oxoniensis.

The important photometric researches of Professor C. Pritchard, conducted at the Oxford University Observatory, from the year 1881 to the present time, have culminated in the publication of a photometric survey of all stars visible to the naked eye from the North Pole to about 10° south of the Equator, which in more than one respect is unique in the history of astrometry.

Under the appropriate title of the "Uranometria Nova Oxoniensis," Professor Pritchard has given the results of some 70,000 instrumental measures, made with the wedge photometer, of the brightness of those visible stars whose magnitudes had been estimated by Argelander by eye observations, and published in his "Uranometria Nova" in 1843. While rendering a tribute to this former important work, Professor Pritchard truly remarks that the requirements and progress of modern astronomy demand greater exactitude than that which Argelander's work justly claims, and a precision exceeding any that can be expected from observations made with the unaided eye.

The work commences with a concise and interesting general historical survey of astronomy, with a brief reference to the various photometers which have been devised to determine stellar magnitudes, forming an epitome of the more extensive and important history of the subject given by the author in vol. xlvii. of the Society's "Memoirs."

The same memoir contains an exhaustive discussion of the theory of a neutral tint glass wedge. The fundamental principle on which the wedge photometer is constructed is enunciated thus in the work under consideration: "The light lost in passing through the medium measured by the alteration of magnitude is proportional to the thickness of the absorbing medium through which it has passed."

Two wedges, A and B, were employed in making the observations attached to two telescopes, one of 4 inches and the other of 3 inches; wedge A, 6½ inches long, 1 inch broad, and 0·145 inch thick, tapering off to 0·02 inch; and wedge B, 4 inches long, 0·110 inch thick, tapering off to 0.02 inch. In wedge A the mean wedge interval required for the absorption of the light of one magnitude is 0.514 inch; in wedge B this interval is 0·385 inch.

The wedge is enclosed in a brass cellular rim with bevelled edges, one of which is divided into tenths of inches. It slides in a groove in the brass cap of the eye-piece of any telescope close to the achromatic eye-lens, and is thus placed between the eye of the observer and the telescope. In the focus of the eye-lens is a diaphragm pierced with a number of small holes, which vary from 0·01 inch to 0·25 inch in diameter, and in which small circular hole the telescopic image of a star is carefully placed, and there viewed through the wedge. Further, the eye of the observer is directed along the axis of the lens and of the telescope by means of an external eye-hole placed close to the wedge, and varying from one-twelfth of an inch to one-quarter of an inch. This direction of vision is important. A fiducial mark is drawn on the brass cap of the eyepiece, so that the position of the wedge can be distinctly marked and recorded when the image of the star is just extinguished by the wedge." The effect of this instrumental arrangement is that a star is viewed in a very small field of view; for instance, that of the 4-inch telescope employed is only about eighty seconds of arc in diameter, and the author claims in his discussion of the "freedom of the measurements from the influence of background," that by restricting the field of view by means of the diaphragm the influence of neighbouring bright stars is rendered insensible.

The method of using this photometer was to select about ten stars for a night's work, such that they could be observed at about the same altitude as *Polaris*. The standard star *Polaris* was extinguished at the beginning, the middle, and the end of the observations. The readings of the wedge were taken five times with the full aperture of both telescopes. A cap was then placed on each object glass, reducing the aperture to one-half, and five extinctions were again made, this second series of readings forming an excellent check upon the first. Thus were obtained for each star with wedge A five extinctions with apertures of 4 inches and 2 inches respectively; and with wedge

B the same number of extinctions, with apertures of 3 inches and 1½ inches.

Professor Pritchard gives a table showing the particulars of numerous repeated measures of sixteen selected stars, which reveals a very remarkable consistency in the observations and a very small mean error. The consideration of this table leads the author to the conclusion that after a certain number of observations nothing is gained in point of accuracy by the multiplication of observations. The mean error of a single extinction is 0·3 of a magnitude; the mean error of a single determination of magnitude as given by ten or twenty extinctions is under 0·1 of a magnitude.

Several sources of error in making observations are discussed by the author. To test whether the eye gets possibly fatigued during any considerable series of observations on any single night, comparison is made between sets of observations of *Polaris* made on separate nights, but without trace of a systematic difference. This is probably the experience of most of those who have worked in the same line. But consistency in the individual extinctions of stars can only be secured by preserving the eye in a normal condition of strain, for any additional effort of the eye will probably cause the star to be extinguished at a denser portion of the wedge. It would therefore have been more interesting and to the point if the author had compared consecutive observations made on the same night, rather than the mean of observations made on different nights.

Professor Pritchard has eliminated such probable errors by his admirable method of observation which secured for each star at least twenty separate extinctions, made with what virtually amounts to four different telescopes. The measures are strictly differential, the mean of the three sets of readings of the extinction of *Polaris* being used for all the observations of the series.

The results of this extensive and remarkable photometric work are contained in a catalogue in which the stars are arranged in constellations. The following particulars are given in the catalogue reference number: Star's Designation, Approximate Co-ordinates for the Epoch 1890, Adopted Zenithal Magnitude on the assumption of the magnitude of *Polaris* being 2.05, Average Deviation in Magnitude, Date of Observation, and the Magnitude in Argelander's "Uranometria Nova." The number of extinctions is not given, but it is presumably twenty for each star. The notes which are appended show, however, that the final magnitude of many stars depends upon a much larger number of observations made on different nights, the accordance between determinations made at wide intervals of time being very noteworthy.

The comparison of Professor Pritchard's star magnitudes with determinations by Professor Pickering and other observers shows satisfactory agreement in the majority of cases; and the

small values of the average deviation in magnitude suggest a remarkable consistency in the observations, and indicate the high value that must be attached to this photometry. The accomplishment within four years of so probably accurate a photometric determination of 2,784 stars visible to the naked eye from the Pole, to 10° south of the Equator, will always reflect honour on Professor Pritchard and his able assistants, Mr. W. E. Plummer and Mr. C. Jenkins.

Professor Pritchard's claims to the gratitude of astronomers will be more fully referred to in the President's address.

Dr. Müller's Sidereal Photometry.

Dr. Müller's photometric researches have been conducted entirely at Potsdam, and have been generally confined to the determination of the coefficient of atmospheric absorption. The observations extend over a period of four years, and have required some 36000 settings of the instrument. Dr. Müller's entire plan embraced, besides the determination of the extinction of light in the atmosphere, the measurement of the brightness of the larger planets and of a considerable number of the smaller, including also the variation of the light in interesting variable stars. Only the first portion of his programme is yet complete, and his investigation differs from that of Seidel in pursuing the enquiry in closer proximity to the horizon, and in giving special consideration to the influence of the extinction on coloured stars.

The Zöllner photometer employed was provided with two object glasses, one of 37·2 mm. and the other of 35 mm.; their focal lengths being respectively 393 mm. and 122 mm. Either aperture could be reduced by diaphragms to 31·0, 22·5, 15·0, and 9·0 mm., and the intensity circle could be read by verniers to $\frac{1}{10}$ of a degree. The colorimeter was supplied with a rock crystal plate (left-handed) 5·020 mm. in thickness.

Dr. Müller refers to the two disadvantages of the Zöllner photometer, viz. the want of constancy in the flames, and the appearance of the artificial star. The first of these disadvantages Dr. Müller believes he has eliminated by his frequent reference to *Polaris*; and, moreover, he contends he has kept the flame constant for five hours. He admits that the steady and somewhat dull light of the artificial star is a disadvantage when the artificial image is compared with stars, and is one which can only be partially removed by practice.

Experiments have been made, principally with the object glass of shorter focal length, to determine the amount of light lost by the introduction of the various diaphragms. The results are as follows:—

$$\log \frac{h^{I}}{h^{IV}} = 0{\cdot}3695,\ \log \frac{h^{II}}{h^{IV}} = 0{\cdot}3439,\ \log \frac{h^{III}}{h^{IV}} = 0{\cdot}2687,$$

the accents showing the diaphragms employed. The theoretically computed values are 1·0742, 0·7959, and 0·4437. Dr. Müller considers that this very striking difference between theory and fact might be attributed partly to the imperfection of the object glass employed, being of so short a focal length, and partly to the operation of the parallel plane glass plate through which the rays pass. With the second object glass the differences are not so conspicuous; and with a telescope of 135 mm. (5·3 inches) apertures the difference vanishes.

The examination of the instrument contains an elaborate determination of the brightness of certain stars in various positions of the colorimeter, compared with those of other observers, viz. Zöllner, Rosen, Ceraski, and Peirce. The result of the comparison, which is also exhibited graphically, shows that there exists a similarity of result among the various observers, but the agreement is by no means exact.

The stars selected for Dr. Müller's determination of the coefficient of absorption were *α Cygni*, *η Ursæ Maj.*, *δ Persei*, *α Aurigæ*, and *α Tauri*, the last added on account of its red colour, though its meridional zenith distance at Potsdam is 36°.

The constant of absorption was obtained for each star, and the mean result is "that the brightness of a star seen in the zenith is 0·8250, if the brightness of that star, without the existence of the atmosphere, be represented by 1." A table is given exhibiting for every degree of zenith distance down to 88° the corresponding atmospheric absorption.

The finally resulting zenith magnitudes of the afore-mentioned stars on the assumption of *Polaris*=2·05 mag., and compared with the Oxford and Harvard results, are as follows:—

Star.	Magnitude determined by Dr. Müller.	Adopted Magnitude at Oxford.	Adopted Magnitude at Harvard.
α Cygni	1·35	1·32	1·37
η Ursæ Maj.	1·91	1·77	1·92
δ Persei	2·98	3·11	3·08
α Aurigæ	+0·77	+0·92	+0·92
α Tauri	+0·10	1·12	+0·10

Herr Wolff's Sidereal Photometry.

Herr Wolff commenced his photometric work at Palermo, where he was compelled to pass the winter of 1869–70, and continued it at Bonn, with more or less regularity, as was unavoidable for a private observer, until April 27, 1875. The instrument made use of was a Zöllner photometer, of 37·5 mm. (1·5 inches) aperture, and of ·375 m. (14·8 inches) focal length. The result was the measurement of the light of 475 stars from the first to the sixth magnitude, but expressed not in magnitude,

but as logarithms of the light compared with that of the mean condition of his lamp, and actually as it burnt on Dec. 8, 1873. There was more recently published a further catalogue, carried on till March 5, 1883, making the total number of stars observed 1130. Herr Wolff, in his first publication, adopted Seidel's coefficient of atmospheric absorption without alteration; but in his more recent work he made some observations of his own for the determination of this constant. The result was ·234 mag. instead of Seidel's ·250 mag. Müller of Potsdam's coefficient is ·209 mag.; Pritchard's at Oxford ·253 mag.

There are two remarkable peculiarities in Herr Wolff's photometric determinations. The first is, that the observed quantity of light transmitted through varying apertures differs greatly from the theoretically computed quantity; and, secondly, the logarithms of the ratios of the lights for different stars, when converted into magnitude on a uniform scale, differ by a gradually increasing quantity, depending on the magnitude from all other investigations of this character. It is not easy to suggest a satisfactory solution of this second difficulty, but inasmuch as perfectly reliable results have been obtained from the Zöllner photometer by other astronomers, it would seem that the solution must be sought for in some subjective cause peculiar to this observer. Professor Pickering has endeavoured to remove what he regards as the systematic error in these researches, and reduces Herr Wolff's numbers to consistency with his own determination by the application of the corrections shown in the following table:—

Limits of Magnitude.		Reduction.	Limits of Magnitude.		Reduction.
	mag.	mag.	mag.	mag.	mag.
Brighter than	+0·7	0·00	3·3 to	4·2	+0·60
+0·7 to	+0·3	+0·10	4·3 to	4·7	+0·70
+0·2 to	1·2	+0·20	4·8 to	5·2	+0·80
1·3 to	1·7	+0·30	5·3 to	5·7	+0·90
1·8 to	2·2	+0·40	5·8 to	6·2	+1·00
2·3 to	3·2	+0·50			

Astronomical Photography.

The greater capabilities of photography, through the increased sensitiveness of the modern dry plate, in its application to astronomical work, become every day more apparent. The most recent successful results, particularly in stellar photography, have been obtained during the past year by MM. Paul and Prosper Henry, of the Paris Observatory. From an account by Admiral Mouchez in the *Comptes Rendus* of May 11, 1885, in which some of the results of the early trials of the new telescope are given, it appears that some experiments made in 1884, with an aperture of $0^{m}{\cdot}16$, decided them to make a larger instrument especially for photography, and in a very short time,

considering the work of calculation and actual making, an objective of $0^m{\cdot}34$ aperture and $3^m{\cdot}43$ focal length (this focal length was chosen to give one minute of arc to one millimetre) was made and mounted equatorially on the English form. Placed parallel to the photographic telescope, if such a term can be used, is a telescope of similar focus and $0^m{\cdot}24$ aperture, for the purpose of watching and directing the movement of the instrument, during exposure, by the ordinary means.

Work was begun in May, and the results have been most remarkable; their enumeration below will make it evident that the great expectations formed by the early workers in astronomical photography are about to be fully realised.

(1) Stars as faint as the fifteenth and sixteenth magnitude have been photographed, and plates of more than 2° each way of portions of the Milky Way, with from 30 to 60 stars down to the fourteenth or fifteenth magnitude to the square centimetre of plate; that is, from 1080 to 2160 to every square degree distinctly shown, with an exposure of one hour. On some plates three separate exposures of one hour each are given, the instruments being moved between each to change the position of the image on the plate and form a triangle about 5″ from point to point, so that accidental spots cannot be mistaken for faint stars—a most successful plan as far as the very faint stars are concerned. Enlarged paper prints of some of these plates have been received by the Society, but the fainter stars are not easily seen, nor, in consequence, the triangular arrangement.

(2) A nebula has been discovered in the *Pleiades*, near *Maia*, so very faint that it is doubtful if it has ever been seen, or would have been found otherwise; and, judging from a copy of the original negative published in *L'Astronomie* of Feb. 1886, the nebula near *Merope*, about which there has been so much discussion, is distinctly seen on the plate, whilst the small detached part lying between *Merope* and *Alcyone*, shown on a sketch by Mr. Common in the April number of the *Monthly Notices* for 1880 as having been seen with his 3-ft. reflector, is also distinctly shown. This opens out a possibility of finding nebulæ and charting them, as well as stars.

(3) A photograph of *Saturn* has been taken by direct enlargement of the primary image by means of a non-achromatic ocular giving a magnification of eleven times, which goes far beyond anything yet done in planetary photography, as can be seen from the paper prints that have been received. This photograph gives promise of most satisfactory results from the application of this method of direct enlargement of the primary image to planets, double stars, the Moon, and other objects.

(4) *Hyperion* has been photographed with an exposure of thirty minutes, and the satellite of *Neptune* can be taken in any part of his orbit as it is at present presented to us.

These are results that speak for themselves, and for which the MM. Henry are to be heartily congratulated, not only for the actual labour of working for them, but for the perfection of the optical part of the instrument, the work of their own hands.

In view of these remarkable results the remarks of Mr. Rutherfurd, one of the most successful of the early workers in astronomical photography, made now more than twenty years ago, may be worth repeating. He says in the *American Journal of Science*, page 308, vol. xxxix., after mentioning the construction of a lens specially made for photography, of $11\frac{1}{4}''$ aperture and 14 ft. focal length, "The power to obtain images of the ninth magnitude stars with so moderate an aperture promises to develop and increase the application of photography to the mapping of the sidereal heavens, and in some measure to realise the hopes which have so long been deferred and disappointed. It would not be difficult to arrange a camera box capable of exposing a surface sufficient to obtain a map of two degrees square, and with instruments of large aperture, we may hope to reach much smaller stars than I have yet taken. There is also every probability that the chemistry of photography will be very much improved, and more sensitive methods devised." Judging from the results that he then obtained, there is no doubt that it was entirely to the want of sensibility of his plates that stellar photography has been so much delayed, and that more will evidently be got from greater sensitiveness of the plate than from mere increase of aperture.

The extent to which accurate measurements of the positions of stars on the photograph can be carried becomes interesting in view of the many questions depending on such accurate measurements. The size of the image on the plate varies (with an equal exposure) according to the brightness of the star (neglecting any difference in colour), and with the telescope of MM. Henry and an exposure of an hour, images of stars of the 14th to 15th magnitude have a diameter of about one-thousandth of an inch—that is, equal in arc to about $1\frac{1}{2}''$. Stars of the 5th or 6th magnitude reach a diameter of about $1'$.

As far as can be seen, the growth of the image is quite concentric with the point of the plate on which the image of the star falls, and that a centre found by measuring from the edge of the image of a large star would be the actual centre, such as would be shown by a sufficiently short exposure. This is shown in a remarkable way in those photographs of MM. Henry where three exposures of one hour each are given, and the instrument moved so that the images of each star form a little triangle, as has been mentioned.

On looking at the faintest stars on the plate, they are seen as little groups of three. As brighter stars are examined it is found that the images increase, and at last go on till they overlap, and this goes on till the complete images of any one bright star are

very much larger than the original little triangle, but the appearance is as if three circles nearly as large as the resulting image had been struck from the centre of what would have been in the case of a smaller star the three stars of a group.

Whether it would not be better to take single exposures on one plate, and reserve this for comparison or measurement, taking a plate with three exposures for the purpose of identification, is a point that will be better settled by time. For stars of similar brightness, or within a few magnitudes of each other, the images not being much more than from ·001 in. to ·01 in. in diameter, thus being about $1\frac{1}{2}''$ to $15''$, the accuracy with which the distances of the centres could be determined might be safely put at from $\frac{1}{4}$ to $\frac{1}{8}$ of the smaller quantity; and by judicious enlargement and comparison the shift of the stars *inter se* could be detected by a much smaller amount.

In a letter published in the *Monthly Notices* for last November, Admiral Mouchez, writing under date of June 20, states that it is the intention to use this photographic telescope to continue their Ecliptic Charts, but he also suggests that, with the co-operation of six or eight observatories the whole heavens should be charted in a similar way. He states how this may be done, and it is to be hoped that he may be able to get such a desirable work done in the way he suggests.

At the Cape of Good Hope, as will be seen from the report of Dr. Gill, considerable progress has been made in getting a *Durchmusterung* of the southern heavens, but on a much smaller scale than that proposed by Admiral Mouchez. An instrument, slightly inferior in power to that of the Paris Observatory, is in course of construction for use, as mentioned in the report referred to.

Mr. Roberts, in England, has erected a reflector of 20 inches aperture, and 100 inches focus, for stellar photography, and made considerable progress in the work he has undertaken of charting the northern heavens by this instrument. Other observers contemplate this class of work, so that soon there will be a means of arriving at some opinion as to the best plan to follow in the future, both as regards the instrument, the plate, and the best scale for different investigations.

All the possibilities of stellar photography have not yet been fully realized, and it will require full discussion of the work in hand and to be done, before these can be seen, but judging only by what has already been done, there is a certainty that much valuable data will be accumulated for the astronomer at present and in the future, with very much less labour and in a better manner than by the old methods.

The American Eclipse Expedition to Caroline Island.

The Report of the American expedition to Caroline Island to observe the Total Solar Eclipse of May 6, 1883, has been published

during the past year by the American National Academy of Sciences.

The United States Government having generously undertaken this expedition, placed it under the able direction of Professor E. S. Holden, and the complete and exhaustive character of the Report, as an account of the operations and a history and monograph of this almost unknown island, reflects high credit upon their selection.

The results of the Eclipse observations have already been briefly noticed by the Council.

The volume under consideration commences with an account of the long journey from New York to Caroline Island, a distance of 8000 miles, and back *viâ* San Francisco.

The position of this island, as determined by the expedition is in longitude west of Greenwich $10^h\ 0^m\ 57^s \cdot 6 = 150°\ 14'\ 24''$, and latitude $10°\ 0'\ 0''{\cdot}59$ south.

Mr. Winslow Upton contributes an interesting report on the meteorology of the island, including observations of solar radiation made during the Eclipse, to determine what proportion of heat received by the earth was cut off by the concealing of the Sun, and the results are very fully discussed. The instruments used on the day of the Eclipse were conjugate thermometers, Violle's bulbs with black bulb thermometers, and ordinary black and bright bulb thermometers. The conclusions arrived at are that, as the readings of all the instruments were essentially the same at the close of totality, and agreed with the observed air temperature, this indicates that during the total phase no heat was received by the earth from the atmosphere so far as these instruments allowed of its measurement. During the Eclipse the amount of heat gradually diminished until practically none was received, and the temperature of night was attained. In the chart of relative intensity appended, the maximum point of the curve appears to be about four minutes after the first contact; the minimum point is about three minutes after the observed time of third contact, and the second maximum about four minutes after last contact.

The astronomical part of the volume is mainly occupied by Dr. Hasting's account of his spectroscopic observations, which have been noticed in a former Report, and a discussion of the theory of the corona advanced by him. At present his views have not met with acceptance among astronomers.

A report on the Fauna and Flora of this small island, only seven or eight miles long and two or three miles wide, and a full account of its physical geography, make up a monograph of an expedition which in many ways is unique, and was carried out in a most satisfactory manner by Professor Holden.

Professor Langley's Researches on Solar Heat.

During the past year the Signal Service Department of the United States has issued a valuable report, by Professor Langley, on Solar Heat. The Professor has for some years been studying the subject at the Allegheny Observatory with actinometers and his own bolometer, by which he can examine not only the total heat received from the Sun on a surface, but also the amount conveyed by very small portions of the spectrum, and, having arrived at results as to atmospheric absorption somewhat differing from those usually received, he desired to confirm them by experiments under specially favourable circumstances.

Being supplied with funds by the liberality of a private individual, and with the aid and support of the chief and staff of the Signal Service, he resolved to make observations of absorption at the top and bottom of a mountain of considerable height in the southern part of the western States, and, if possible, to select one such that the abruptness of its rise would allow a station at the top to be very close to the one at the bottom, and to seek a clear dry air.

Finally Mount Whitney, in lat. 36° 35′ N., long. 118° 30′ W., was selected, and in the second chapter of his Report he tells the story of his work, involving a journey across a treeless, waterless desert in the heat of July and August. All the projected work did not succeed, but the results confirmed and added to the conclusions he had reached at Allegheny.

He says, "We conclude that the action of our atmosphere is incomparably more complex than ordinary theory assumes it to be, and that even were we provided with a better theory, causes not yet fully understood introduce systematic errors into high and low Sun observations, tending to impair the results of the best observer at one station, and on the whole to lead him to underrate the amount of the absorption.

"We find, as we ascend in the atmosphere, its transmissibility marked by changing, so that on the whole, quite independent of its lessening density, the air becomes more and more transmissible as we directly ascend it. The transmissibility, as determined by actual observation, without the use of any formula, confirms in the most absolute manner, that, with the exception of the cold bands, the transmissibility increases throughout the spectrum when the wave-length increases, the violet being more transmissible than the ultra-violet, the blue than the violet, the green than the blue, the yellow than the green, the red than the yellow, and the border of the dark heat than the red, until, when we have gone farther down in the spectrum, the transmissibility will become almost complete, except for sudden great interruptions of it—the cold bands—the largest of which we discovered on Mount Whitney.

"Finally,"[A] he says, "my conclusion is that, in view of the large limits of error, we can adopt three calorics as the probable value of the solar constant; by which I mean that, at the earth's mean distance, in the absence of its absorbing atmosphere, the solar rays would raise one gramme of water 3° Centigrade per minute for each normally exposed square centimetre of its surface.

"Though the actual solar radiation is thus largely increased, yet the temperature of the Earth's surface is not principally due to this direct radiation, but to the quality of selective absorption in our atmosphere, without which the temperature of the soil in our tropics would probably not rise above—200° C.

"Generally speaking, the radiation which we see enter we see escape within the utmost known limits of the spectrum. The heat-storing action from checked re-radiation, to which the surface temperature of this planet is due, apparently goes on beyond these limits, where no spectrum measurements have yet been made. *No such wave-lengths as those belonging to heat radiation from the soil, we believe, have ever entered our atmosphere from the sun*, though we admit their existence in the solar spectrum before absorption. Professor Langley's investigation extends the directly-observed spectrum to a wave-length of nearly $\frac{3}{1000}$ of a millimetre, up to which point he says probably the transmissibility of the spectrum increases, but there it suddenly ceases, as if all beyond were an unlimited cold body."

A paper has also been very recently received, in vol. iii. part 1 of the "Memoirs of the National Academy of Sciences," in which Professor Langley expresses an opinion that the temperature of the sunlit surface of the Moon is not far from the freezing temperature, but not so far below as we might expect to find that of an absolutely airless planet.

Maps of the Spectrum.

During the past year two important maps of the solar spectrum have been completed, the one photographic and the other a carefully executed hand-drawing. The photographic map has been made in the dry air of the United States with one of Professor Rowland's concave gratings of 21½ feet radius and 6 inches diameter. A scale of wave-lengths has been added, so that the whole makes a map of the spectrum extending from wave-length 3680 to 5790: that is, from above H down nearly as far as D. The region in the neighbourhood of H is on four times the scale of Ångström's map; the region at the less refrangible end is on twice the scale, and the intermediate portion is on three times the scale, of Ångström. The definition is so good that 1474, b^3 and b^4 are shown clearly as double lines, and E, though not distinctly split, can be easily recognised as double. The wave-lengths of more than 200 lines in the

spectrum have been accurately determined to about $\frac{1}{500000}$ part, and these serve as standards to correct any small errors of the appended scale.

The hand-drawing of the spectrum has been made by M. Thollon with a large bi-sulphide of carbon spectroscope kept at an even temperature by water circulating within the table on which it is mounted, and also within a metal double-walled box which descends from the ceiling and covers the instrument. The light of the Sun is thrown from a heliostat on to the instrument through a window on one side of the metal box, and the observer looks through a telescope passing through the other side of the box. All adjustments of the instrument can be rapidly made by rods and strings passing through the sides of the box. With this instrument M. Thollon has made a map of the spectrum from A to *b*, more than ten mètres long, carefully distinguishing the atmospheric lines from those of solar origin. Each portion of the spectrum is represented by four bands, the upper one of which represents the solar spectrum as observed when the Sun is at a distance of 80° from the zenith, and the air is neither very dry nor very damp. The second band represents the spectrum as seen when the sun is 60° from the zenith and the air is very damp. The third band represents the spectrum as seen when the sun is 60° from the zenith and the air is very dry. The fourth band contains all the lines of exclusively solar origin, and has been constructed by prolonging the lines which remain unaltered under varying atmospheric conditions.

The observations upon which the drawings are based have been principally made at Nice. M. Thollon has been occupied for more than four years in measuring the positions of the 3200 lines included in his map, and in laying them down, paying special attention to the relative darkness of the lines, their breadth, nebulosity, and other characteristics. It is hoped that steel plates from these valuable drawings will be published in the first volume of the *Annales* of the Observatory of Nice, which M. Bischoffsheim intends to publish in the course of next year.

Longitude Determinations.

The United States Bureau of Navigation, in continuation of former similar work by officers of the U.S. Navy, has published a series of telegraphic longitudes of places in Mexico, Central and South America, determined by an expedition under the command of Lieutenant-Commander C. H. Davis, U.S.N.* The methods pursued were identical with those of the former expeditions and leave nothing to be desired in point of accuracy. The

* "Telegraphic Determinations of Longitudes in Mexico, Central America, and on the West Coast of South America."—Washington, 1885.

idea was "to carry the same system of measurements over the cables of the Mexican and Central and South American Companies and the West Coast of America Company, which extend from Galveston in the United States to Vera Cruz, and from Salina Cruz in Mexico in an unbroken line to Valparaiso in Chili." Captain Davis's instructions included the connection of his chain of measurements with the meridian of the national Argentine Observatory at Cordoba, which was the terminal point of the chain of measurements already made on the east coast of South America; so that they might, "by closing a great polygon of meridian distances, all measured by American astronomers following the same methods, determine a new value for the longitude of the Cordoba Observatory, the degree of whose accordance with the one already found would be a measure of the accuracy of the whole work."

The new determinations are: 1, Vera Cruz, which was connected with Galveston, the longitude of which, from the Washington Observatory, had been previously determined; 2, La Libertad, Salvador; 3, Guatemala; 4, Paita; 5, Arica; 6, Valparaiso; 7, Lima; 8, Cordoba, all of which depend upon Panama, the longitude of which had been determined by Commander Green, U.S.N., in 1875.

The longitude of the Argentine National Observatory at Cordoba derived from this new series is $4^h\ 16^m\ 48^s{\cdot}238$ west of the Royal Observatory, Greenwich, while the longitude of the same Observatory, determined in 1878 and 1879 by the chain measured from Greenwich to Buenos Ayres, was $4^h\ 16^m\ 48^s{\cdot}060$, a difference of $0^s{\cdot}178$, which difference "represents the algebraic sum of the errors of the measurements of all the sides comprising the polygon. The measurements are mostly not corrected for personal equation of the observers. A discussion of them, for an adjustment of the several longitudes, will form the subject of a future paper from the Bureau of Navigation."

After a delay of ten to fifteen years the Government Astronomer at Madras has published* the longitudes measured from Madras Observatory in connection with Lieut. Fleuriais' expedition, 1870; the eclipse of the Sun, 1871; and the transit of *Venus*, 1874. The places are Pondicherry, Singapore, Jaffna, Colombo, Karachi, Muddapur, and Roorkee. The differences of longitude all depend upon exchanges of telegraphic signals, but from the special circumstances of each case, comparisons for the estimation of the relative personal equations of the observers were impossible. For the time observations at Madras the result of the transit of each clock star is given. No allusion is made to the errors of collimation, level, or azimuth, or other instrumental corrections, or to the authority for the R.A.'s of the stars observed. On the other hand the whole of the signals are printed in detail. Except for Pondicherry and Avanashi, no

* "Telegraphic Determinations of the Difference of Longitude, &c."—Madras, 1884.

details whatever are given of the time determinations at the other places. Some of these, however, have been published elsewhere. Considering that only a few hours' labour were necessary to deduce the longitudes from these clock comparisons, and the natural desire of those with whose co-operation and for whom the work was done to obtain the results in reasonable time, the delay in this publication is without a parallel in the history of astronomy; by it the colony of Ceylon has been deprived of the benefit of a good longitude for fourteen years, during which period all the officers who took an interest in the work have either died or left the colony.

A work of quite exceptional character in this branch of astronomy has been recently issued by the Earl of Crawford and Balcarres.* It contains the whole of Mr. Gill's work on the longitudes and latitudes during the private expedition to the Mauritius for the observation of the transit of *Venus*, 1874. The determination of the longitude of Belmont, Mauritius, by the transportation of fifty chronometers from Aden and back, formed a main feature of the expedition. The authors hoped that the most scrupulous attention to the temperature corrections of the chronometers would result in a longitude of Belmont measured from Aden comparable, as regards accuracy, with the only other method available, the lunar. On the outward journey the interval of time which the chronometers had to measure was twenty days; on the homeward journey thirteen days.

During their residence at Mauritius the observers connected their station with that of the British Government on the Island of Rodriguez by the transportation of some fifty chronometers on board H.M.S. *Shearwater* with Mr. Meldrum's Observatory at Pamplemousses, and with the German station at Solitude by telegraph; while on the return journey to Aden connection was made with the Dutch observing station on Réunion, and, with the co-operation of Commander Wharton, a longitude of the Seychelles was obtained. Fully one-half of this large volume is devoted to the telegraphic longitudes of Malta, Alexandria, Suez, Aden, and Bombay, the two first-named by exchange of signals direct with the Berlin Observatory. The longitudes of Alexandria and Suez had been previously obtained by the British Government expedition to Egypt in connection with the transit of *Venus*, by direct signals from Greenwich; and Aden and Bombay have been since re-determined by the officers of the Trigonometrical Survey of India. The differences of the double determinations are in all cases very small, as was to be expected.

This volume, in which everything is printed in the most elaborate detail, is at once a monument to the astonishing energy characterising the work of the principal observer, Mr. Gill, and to the ability and munificence of the noble originator of the enterprise.

* Dun Echt Observatory Publications, Vol. III.. 1885.

Papers read before the Society from February 1885 *to February* 1886.

1885.

Mar. 13. On the proposed change of the astronomical day. Professor S. Newcomb.

Note on the track of the total phase in the total Solar Eclipse of 1885, Sept. 18, in its passage across New Zealand. J. R. Hind.

Phenomena of *Jupiter's* satellites and occultations of Stars by the Moon observed at Stonyhurst, 1884. Rev. S. J. Perry.

Account of some physical observations of *Venus* in 1884. A. Stanley Williams.

Solar Eclipses and occultations by the Moon (with diagram of the Solar Eclipse Aug. 28–29, 1884, at Granada, West Indies). Rev. J. Pearson.

On variations in the light of β *Lyræ*. E. von Gothard.

Observations of Barnard's Comet (*b* 1884), made at the Natal Observatory. E. Neison.

On the value of the long inequality in the motion of the Moon, due to the disturbing action of the planet *Mars*. E. Neison.

On the proposed change of the astronomical day. Professor Th. von Oppolzer.

Notes and corrections to Sir John Herschel's synopsis of all Sir William Herschel's measures. H. Sadler.

Jupiter's IVth satellite. E. J. Spitta.

Note on the transit of *Jupiter's* satellite IV., seen at Clapham, 1885, Feb. 27. E. J. Spitta.

Note on the *Nautical Almanac* dimensions of the Saturnian system. Captain W. Noble.

On the right ascensions of the Cape Catalogues for 1850 and 1880. A. M. W. Downing.

On the star places of the *Nautical Almanac*. A. M. W. Downing.

Spectroscopic results for the motions of Stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1884, No. VIII.

April 10. Occultations of Stars by the Moon in the years 1876-80, and resulting final equations between the errors of

April 10. the tables and the errors of observation. G. L. Tupman.
The periodicity of Solar Eclipses. Prof. C. V. Zenger.
Occultations observed at Forest Lodge, Maresfield. Captain W. Noble.
Occultation of *Aldebaran*, 1885, February 22, observed at Dun Echt, Aberdeen. Dr. R. Copeland.
Observation of the projection of *Jupiter's* 1st satellite on its own shadow, 1885, February 18, made at Dun Echt, Aberdeen. Dr. R. Copeland.

May 8. Observing weather. Rev. S. J. Johnson.
Five orders of Meteor-streams or Comets. R. A. Proctor.
Total Solar Eclipses visible in the British Isles in the years 878–1724. J. Maguire.
Observations of Comet 1884, III. (Wolf) at Harrow. G. L. Tupman.
A peculiar variety of Meteors. W. F. Denning.
Observations of *Saturn*. N. E. Green.
Note of an observation during the transit of *Jupiter's* satellite IV., 1885, April 18. E. J. Spitta.
On the right ascensions of the Cape Catalogues, 1850, 1860, and 1880. E. J. Stone.
On the diameters of the Sun and Moon as observed with the Greenwich transit-circle. W. G. Thackeray.
Reply to Mr. Stone's paper on screw errors as affecting the N.P.D. of the Cape Catalogue for 1880. David Gill.

June 12. Observations of the satellites of *Saturn* and of the companion of *Sirius* made at the United States Naval Observatory, Washington. Professor A. Hall.
Craters in the Moon. Lieut.-Colonel H. S. Knight.
The velocity of Meteors. W. F. Denning.
Ephemerides of the satellites of *Saturn*, 1885-86. A. Marth.
Ephemeris of the satellite of *Neptune*, 1885-86. A. Marth.
Elliptic elements of Comet 1883, II. (Ross). R. Bryant.
On Al-Sûfi's Star magnitudes. E. B. Knobel.
On daylight occultations of *Aldebaran* in 1885. J. R. Hind.
On some points of difference between the Harvard and Oxford Stellar Photometry No. 1. Prof. C. Pritchard.

Nov. 13. Observations of the companion of *Sirius*, made at the Dearborn Observatory, Chicago. Prof. G. W. Hough.
Observations of Comet, 1884 (Wolf) made at the Royal Observatory, Cape of Good Hope.
Observations of Comet 1884 (I.) (Pons-Brooks), made at the Royal Observatory, Cape of Good Hope.

Nov. 13. Observations of Comet 1884 (II.) (Barnard), made at the Royal Observatory, Cape of Good Hope.

On the application of a Nicol's prism to sextant observations. Captain T. Mackenzie.

The horizontal and vertical diameters of the Sun, as observed with the Greenwich transit-circle. W. G. Thackeray.

Total Solar Eclipses, A.D. 878 to 1724. J. Maguire.

Note on stationary radiant-points. R. A. Proctor.

On the proper motions of the stars L L 31296 and 31188. G. L. Tupman.

Observations of Comet 1885 (Barnard) at Harrow, with the 18½-inch equatorial reflector and ring micrometer. G. L. Tupman.

On a suspected new variable star in *Corona Borealis*. G. F. Chambers.

Ephemeris for physical observations of *Jupiter*, 1885–86. A. Marth.

On Al-Sûfi's and Ptolemy's Catalogues (extract from a letter to Mr. Knobel). Professor Schjellerup.

Daylight occultation of *Aldebaran* on July 9, 1885, observed at Forest Lodge, Maresfield. Capt. W. Noble.

On the reduction of Bessel's precessions to those of Struve. A. A. Rambaut.

Note on Mr. Chambers's suspected new variable in *Corona Borealis*. Rev. T. E. Espin.

Notes on the Total Solar Eclipse of 1885, September 9, viewed at the Terrace, Wellington, New Zealand. C. R. Marten.

Erratic Meteors. B. J. Hopkins.

Ephemeris for physical observations of *Mars*, 1886. A. Marth.

Photometric observations of the Nova in the *Andromeda* nebula, made at the Oxford University Observatory. Professor C. Pritchard.

On Dr. Wilsing's experimental examination of the wedge-photometer; and (II.) on the degree of accuracy attainable by means of that instrument. Professor C. Pritchard.

The outburst in *Andromeda*. Rev. S. J. Perry.

Observations of the spectrum of the new star in the great nebula in *Andromeda*, made at the Royal Observatory, Greenwich. E. W. Maunder.

A new form of governor for the driving clocks of equatorials. A. Hilger.

Proposal for photographing the heavens. (Letter to the President, from Admiral Mouchez.)

Dec. 11. On a suspected new variable star in *Corona Borealis*. J. E. Gore.

Dec. 11. Observations of double stars at Windsor, New South Wales. J. Tebbutt.

The *Andromeda* meteors. J. Rand Capron.

Notes of the Meteorites of Nov. 27, 1885, as seen at East Tisted Rectory, Alton, Hants. Rev. F. Howlett.

On the orbit of γ *Coronæ Australis*. J. E. Gore.

The Meteoric display of 1885, Nov. 27. Col. M. F. Ward.

Meteor shower connected with Biela's Comet. Rev. S. J. Perry.

Occultation of *Uranus* 1885, Dec. 1. Rev. S. J. Johnson.

On the term of long period due to *Mars* in the expression for the longitude of the Moon. E. Neison.

The Meteoric shower as seen at Clapham on the night of Nov. 27, 1885. E. J. Spitta.

Ephemeris for the satellites of *Uranus*, 1886. A. Marth.

The Biela Meteor shower of Nov. 27, 1885. Professor C. Pritchard.

Observations of the Meteor shower of Nov. 27, 1885, made at the Glasgow Observatory. Professor R. Grant.

On the Meteoric shower of Nov. 27, 1885. Dr. R. Copeland.

Observations of Comets Brooks, Fabry, and Barnard made at Dun Echt Observatory with the filar micrometer of the 15-in. refractor. Communicated by Lord Crawford.

La grande pluie des étoiles filantes du 27 Novembre, 1885. F. Denza.

The great shower of *Andromedes* Nov. 26, 27, 28, and 30, 1885. W. F. Denning.

General catalogue of radiant-points of shooting-stars. W. F. Denning.

Observations and orbit of the Meteor shower of 1885, November 27. G. L. Tupman.

Observations of magnitude of *Nova Andromedæ*, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

On the connection between photographic action, the brightness of the luminous object, and the time of exposure as applied to celestial photography. A. C. Ranyard.

Comparison of Groombridge's and Struve's right ascensions of close circumpolar stars. Prof. T. H. Safford.

Jan. 8. Observations of the Biela's Comet meteors, made at the Royal Observatory, Greenwich.

The Meteor shower of 1885, November 27. Major G. Strahan.

Jan. 8. The Meteor shower of 1885, November 27. Major A. C. Bigg-Wither.

On a new spectroscopic method for measuring close double stars. Prof. C. V. Zenger.

Photographic maps of the stars. I. Roberts.

On a new variable star of short period. J. E. Gore.

Observations of Comet 1885 (Brooks) at Harrow with the 18½-inch equatorial reflector. G. L. Tupman.

On the new star in *Orion*. J. E. Gore.

Observations of the Meteors of 1885, November 27, made at the Radcliffe Observatory, Oxford. W. H. Robinson.

Display of Meteors, 1885, November 27. W. Wickham.

Note on the Biela Meteors. R. A. Proctor.

Ephemeris of the satellites of *Mars* 1886. A. Marth.

On the variation in colour of the *Nova Andromedæ*, and on the evidence it affords as to the origin of the *Nova*. B. J. Hopkins.

Note on Mr. Marth's "Intersects." H. H. Turner.

On a new star in the constellation of *Orion*. Dr. R. Copeland.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1885, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Note on the Transit of the planet *Mars* and its satellites across the Sun's disk, which will occur for the planet *Jupiter* and its satellites on April 13, 1886. A. Marth.

Changes in the red spot on *Jupiter*. W. F. Denning.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1885, No. IX.

Observations of Comets *d* 1885 (Fabry) and *e* 1885 (Barnard), made at the Royal Observatory, Greenwich.

Observations of occultations of stars and *Uranus* by the Moon and of phenomena of *Jupiter's* satellites made at the Royal Observatory, Greenwich, in the year 1885.

Observations of the spectrum of *Nova Andromedæ*, made at the Royal Observatory, Greenwich. E. W. Maunder.

On photographs of a new nebula in the *Pleiades*, and of *Saturn*. (Letter to the President, from M. Henry.)

List of Public Institutions and of Persons who have contributed to the Library, &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The Norwegian Government.
British Association for the Advancement of Science.
British Horological Institute.
Geological Society of London.
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Meteorological Office.
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Physical Society of London.
Royal Asiatic Society of Great Britain.
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Adelaide, Royal Society of South Australia.
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Copenhagen, Royal Academy of Sciences.
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Haarlem, Musée Teyler.
Halle, Imperial Leopold-Caroline Academy.
Hamilton Association.
Harvard College Astronomical Observatory.
Helsingfors, Finnish Society of Sciences.
Helsingfors Observatory.
Hong Kong Observatory.
Leipzig, Astronomische Gesellschaft.
Leipzig, Royal Society of Sciences of Saxony.
Madison, Washburn Observatory.
Madras Observatory.
Madrid Educational Institute.
Madrid Observatory.
Melbourne Observatory.
Melbourne, Patent Office.
Milan, Royal Observatory.
Moncalieri Observatory.
Montpellier, Academy of Sciences.

Montreal Geological Survey.
Montreal, Royal Society of Canada.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Natal Observatory.
Neuchatel, Society of Natural Sciences.
New Haven, Connecticut Academy.
New York, Columbia College.
Paris, Academy of Sciences.
Paris, Bureau des Longitudes.
Paris, Dépôt Général de la Marine.
Paris, École Polytechnique.
Paris, International Committee of Weights and Measures.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
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Prague Observatory.
Pulkowa Observatory.
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Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy dei Lincei.
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St. Petersburg, Imperial Academy of Sciences.
San Fernando Observatory.
Stockholm Observatory.
Stockholm, Royal Swedish Academy of Sciences.
Sydney, Government Observatory.
Tacubaya Observatory, Mexico.
Tasmania, Royal Society.
Tiflis, Physical Observatory.
Tokio University.
Toronto, Canadian Institute.
Toulouse, Academy of Sciences.
Trieste, Imperial Nautical Academy.
Turin, Italian Meteorological Society.
Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Washington, Bureau of Navigation.
Washington, Office of the American Ephemeris.
Washington, National Academy of Sciences.
Washington, Smithsonian Institution.
Washington, United States Chief Signal Office.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yale College Observatory.

Yokohama, Seismological Society of Japan.
Zurich, Central Meteorological Institute.
Zurich, Society of Natural History.
Zurich, Swiss Geodetic Commission.
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ADDRESS

Delivered by the President, Edwin Dunkin, F.R.S., on presenting the Gold Medal of the Society to Professor Edward C. Pickering, For. Assoc. R.A.S., and Professor Charles Pritchard, D.D., F.R.S.

GENTLEMEN,

The Council have awarded the Gold Medal conjointly to Prof. Edward C. Pickering, Director of the Observatory of Harvard College, U.S., and the Rev. Charles Pritchard, D.D., Savilian Professor of Astronomy in the University of Oxford, for their "Photometric Researches." It now devolves upon me, as your President, to explain generally the grounds upon which this award is based.

You may remember that in June, 1871, a new bye-law was enacted by the Society, on the recommendation of the Council, to authorise the award of a joint Medal when it appears expedient to recognise the independent researches of two or more persons who have been working independently on the same subject, and who at about the same time have announced publicly the results of their separate labours. In past years much inconvenience has been experienced for want of such a power on the part of the Council, though on one occasion in 1867 means were found to justify the award of a joint Medal. But in this case the recipients were co-workers, and the Fellows, with enthusiasm, condoned that somewhat irregular act of the Council, which apparently was a departure from a course which the bye-laws had prescribed. On inspecting the new bye-law, enacted in 1871, it will be perceived that the Council are now authorised to receive the nomination of two or more persons as joint recipients of the Medal, provided that the nominees are the simultaneous, but independent, authors of any treatise, work, research, or discovery; and the bye-law goes on to say that "should the Medal be ultimately awarded to such joint authors, workers, or discoverers, an impression of the Medal shall be provided for and given to each of such joint recipients." The Council have therefore great pleasure in carrying out, for the first time, the terms of this new bye-law, by their award recognising the important and interesting stellar researches independently carried on by Profs. Pritchard and Pickering, as a comparatively

new subject of physical inquiry, combining new principles and apparatus in the investigation.

Since the appointment of Prof. Pickering to the superintendence of the Observatory of Harvard College he has devoted much time and attention to the subject of the comparative lustre of the stars, the results of which have from time to time been communicated to astronomers. The magnitude of his work on the photometry of the stars was not, however, realised till the appearance in 1884 of the first part of Vol. XIV. of the *Annals of the Astronomical Observatory of Harvard College*, which includes the results of his photometric examination of all stars of the sixth magnitude to 30° south declination. This great work contains chapters giving a detailed description, with diagrams, of the meridian photometer used in the investigation; a summary of the whole series of observations, including a discussion of the estimated magnitudes of *Polaris*, the star to which all other stars were referred; notes on the atmospheric absorption of light; on eye-estimations of the brightness of the stars, visible to the unaided eye, for comparison with the corresponding photometric determinations; and a general catalogue giving in tabular form the main results of the entire investigation. The number of stars included in the catalogue is 4,260, representing 700 series of observations, and 94,476 separate comparisons made between October 25, 1879, and September 17, 1882. The list contains all the stars not fainter than the sixth magnitude between the North Pole and 30° south declination, or as low as stars can be conveniently observed for this purpose in latitude 42° N. The stars were selected from several standard catalogues, in which the magnitude is given as, at least, the sixth. They have all been observed near the meridian, where they have the greatest altitude, thus facilitating the computation of the correction for atmospheric absorption. A second part of the work appeared in 1885, consisting mainly of a detailed discussion and comparison of all the original star-magnitudes found in various original catalogues, from Ptolemy and Al Sûfi to modern times, and it is a discussion of some magnitude, exhibiting in its compilation the results of great zeal and research. In addition to this comparison, the second part includes separate chapters on discordant observations, suspected variables, the distribution of stars, and other subjects.

The instrument devised by Prof. Pickering, and which appears to have been perfectly successful, has been named by him the Meridian-Photometer. It consists of a horizontal telescope pointing to the west, having two similar object-glasses of about four centimetres aperture and 80 centimetres focal length. Right-angled prisms are placed in front of the object-glasses, through which the images of the stars to be measured and the comparison star, *Polaris*, are reflected. The prism through which *Polaris* is reflected may be turned by rods around two axes, one perpendicular to the axis of the telescope, the

other coinciding with it. By these two motions *Polaris* may always be brought into any part of the field of view. The prism which reflects the star to be measured may also be turned around the axis of the telescope, and it carries a graduated circle, divided into degrees, the index of which is so adjusted as to give the declination of the star reflected. This prism can also be inclined by means of a screw so as to vary the collimation if required. A further technical detail of the photometer I give strictly in Prof. Pickering's own words: "The use of two objectives might be expected to produce two separate emergent pencils. Errors would then be caused by a slight movement of the eye of the observer, a portion of one pencil being sometimes cut off by the edge of the pupil. Moreover, we cannot be sure that different portions of the eye are equally transparent. Different pencils would likewise pass through different portions of the eyepiece, and would be unequally reduced by the dust upon its surfaces. To avoid these various sources of error, the double-image prism is placed near the focus of the objectives. This prism is made of Iceland spar compensated by glass. Each pencil is thus divided into two. The northern of the two pencils from the southern objective is made to coincide with the southern of the two northern pencils. This is effected by varying the angles of the spar and glass prism. As the prisms are cemented together, the interval between the two images may be varied by grinding the face of the spar, while a change in the glass face moves both images together. Two or three trials sufficed to make the two central pencils coincide, and pass nearly through the centre of the eyepiece. In front of the latter is placed a Nicol. An eye-stop has an aperture of such a size that it will admit the central pencils and cut off the two outside pencils. By placing this stop a little excentrically, the slight deviation of the pencils in traversing the Nicol was corrected. The pencils forming the images to be compared are therefore coincident, and are formed by precisely similar object-glasses. A graduated circle, divided into degrees, is attached to the eyepiece and Nicol, and on turning it through any angle from the point where one image disappears, the light of that image will evidently be proportional to the square of the sine of the angle. An index serves to measure this angle in degrees and tenths." Some difficulty was at first experienced from the imperfection of the annealing of the reflecting prisms, but this was overcome by a method of local correction, by which a better definition of the images was obtained. Great credit is due to Prof. Pickering for devising the meridian photometer, which in his hands has been so successful; for though it may be considered in some respects an adaptation of previously existing photometers, there can be no question as to the fact that he has introduced so many important modifications that makes it, in reality, a new and original instrument.

Prof. Pickering had the aid of a large staff of assistants dur-

ing the three years occupied by these observations. The following is a brief sketch of the daily routine of work. To observe with the meridian-photometer two persons are required. The image of *Polaris* is first brought by the observer into the middle of the field of view, by the two handles moving the northern prism. An assistant, who records the observation, then, by means of the declination-circle, directs the southern prism to the star to be measured, which is brought into the middle of the field by the collimating screw. "The observer places the image of the Pole-star near that of the star to be measured and makes a setting by turning the Nicol until the images appear to be equal. He then notifies the recorder to enter the reading, which is done to tenths of a degree. On being notified by the recorder that the reading has been made, he turns the Nicol so that the image of the Pole-star just disappears and then regains a brightness equal to that of the other star. This second setting is recorded while the observer reverses the images by moving the northern prism. Two more settings are then made in the same way as before." It was usual to call the work of each observer on a single evening by a distinguishing number or series. Each series was limited to about an hour, the observations being continuous, one star being brought into the field as soon as the preceding star had been measured. By limiting a series to an hour, any injurious effect arising from the fatigue of the eye was diminished.

The success of the meridian-photometer in the investigation before us induced Prof. Pickering to construct a larger instrument of improved form, with which he has been enabled to observe the photometric magnitudes of Neptune, some of the minor planets, and objects generally not fainter than the tenth magnitude. The object-glasses are about four inches aperture and sixty inches focal length, and the instrument differs from the smaller one in many of the details. In his report of the work of the Harvard Observatory from 1877 to 1882, Prof. Pickering states that he intends to employ this larger photometer "in the revision of the stars of the northern heavens where the zones of the various observatories overlap by a small amount. Over eight thousand stars are contained in these overlapping portions. The light of all these stars is to be determined with it, and the estimates of light of the various observers in the entire work of revision may thus be reduced to a single standard. Besides this work, the standard stars of the *Uranometria Argentina*, the comparison stars for variables, and other objects of interest will be measured."

In a more recent report, Prof. Pickering states that the observations with the new meridian-photometer have been regularly continued, and in some measure extended. During the year 1885 more than two hundred series of observations were made, representing upwards of fifty thousand separate settings, or nearly double the number made in the preceding

year. The accordance of the results continues satisfactory, the average deviation of the separate measures of the standard circumpolar stars being about ·12 of a magnitude. In order to increase the regularity of distribution of the stars observed, other zones of 20′ in width have been added to those previously selected for observation, so that the entire series now includes zones at intervals of five degrees from the equator to the pole.

In some instances Prof. Pickering has adopted the wedge-photometer for the determination of the photometric magnitudes of the fainter class of objects, as in the revision of the magnitudes in the *Durchmusterung*; faint stars selected as standards of magnitude in twenty-four regions following bright stars; and also stars which have been used as standards of comparison for variable stars. When these comparison stars are of sufficient brightness, they have been usually measured by the meridian photometer, and their magnitudes, thus determined, serve as a basis for the measurement of the fainter stars by the wedge-photometer. "Two observations of each star not determined by the meridian-photometer, and of a sufficient number of the others, are made with the wedge on each evening when the region occupied by the comparison stars of any particular variable is observed. Two complete observations of this kind, made on different evenings, are regarded as sufficient; but when moonlight or other causes render the work of either evening imperfect, it is repeated on a third evening." Prof. Pickering does not consider that the wedge-photometer employed at the Harvard Observatory is capable of the great degree of precision claimed for the Oxford photometer, and in order to ascertain whether this difference is due to the form of the instrument, he has requested Prof. Pritchard to superintend the construction of a wedge-photometer, upon the same plan as that at Oxford, for use at the Harvard Observatory. This instrument is now completed by Mr. Hilger, and is, or soon will be, in the hands of Prof. Pickering.

For the determination of the law of atmospheric absorption, Prof. Pickering selected 100 of the brighter stars, none being fainter than the sixth magnitude, between 60° and 75° north declination, some of which were observed on each evening at their upper and others at their lower culmination. A table is given showing the observed magnitude of each star, from which the adopted coefficient of absorption has been determined to be ·250. The diminution of brightness at the lower culmination indicates to what extent the magnitude of the star is affected by the atmosphere.

It is impossible, in the brief time at my disposal, to do full justice to Prof. Pickering's excellent work, and consequently I must reluctantly pass over many points of interest worthy of attention, and confine my remarks for a few minutes to the general catalogue of results containing all the main details of the investigation. The system of abbreviation, once understood, is

a great convenience, as it increases the space for the insertion of more facts and references. The catalogue, as I have already stated, contains the fullest particulars relating to the photometric observation of 4,260 stars. A mere glance at its crowded columns, extending over 173 pages, is sufficient evidence of the magnitude of the undertaking, the produce of only three years' observation, and less than two years' subsequent computation and research. The catalogue gives the names of the constellations; the designating letters and numbers in various standard catalogues; the approximate right ascensions and declinations for 1880; the eye-estimated magnitudes according to the *Uranometria Nova*, the *Atlas Cœlestis Novus*, the *Durchmusterung*, and the *Uranometria Argentina*; the photometric measures and probable errors; the number of the series; the residuals in tenths of a magnitude, obtained by subtracting the mean photometric magnitude from the separate results of the photometric measures; the corresponding residuals of the separate direct estimated magnitudes; and the results of no less than fourteen series of estimates of antecedent astronomers, commencing with Ptolemy, compared with the mean photometric magnitudes, the residuals being expressed in the same form as for the direct estimations. These former estimates have been reduced to one uniform scale by a method explained by Prof. Pickering.

In April 1879, a circular was issued from the Harvard Observatory, in which was suggested the employment of certain stars very near the North Pole as photometric standards of stellar magnitude. In connection with this proposal, seven stars, sufficiently bright, were observed for this purpose. Four of these—*Polaris*, ô *Ursæ Minoris*, *Cephei* 51, and λ *Ursæ Minoris*—are included in the general catalogue, the photometric magnitudes of the remaining three being 6·5, 8·0, and 8·8 respectively. Omitting *Polaris*, from fourteen to seven measures of each star were obtained with a mean probable error of ·04. The photometric measures of twenty-six stars in the *Pleiades* group have also been made and compared with the eye-estimations of Bessel, Argelander, C. Wolf, Pritchard, and Lindemann. The residuals are no greater than might have been expected, those of Pritchard and Lindemann being very small. These are only a few of many other miscellaneous series of photometric observations undertaken by Prof. Pickering, to which my limited time will not permit me to allude. I may, however, again remark that stars known to have been used as standards of comparison for variable stars, especially those employed by Argelander, Schönfeld, and Oudemans, have been observed with the meridian-photometer as far as practicable. He has also successfully applied the principle of polarisation of light to the photometry of double stars.

It has struck me very forcibly, while examining the columns of residuals in the general catalogue, that the average deviations from the mean are in most cases within reasonable limits; yet

in many instances they are considerable, far exceeding what we might expect in an observation of this kind. Possibly, in a few cases, the wrong object has been observed, though Prof. Pickering remarks that this could not frequently have been done, as there were several checks adopted to assist in the identification of the object. There may be other causes for the large deviations, such as the varying effects of atmospheric absorption produced by mist or unobserved passing clouds, and sometimes from the rapidity with which the observations were made. As a rule, however, the effect of these apparently large discordances, amounting occasionally to a whole magnitude, is probably for the most part eliminated in the mean result.

With regard to the accidental errors contained in the catalogue, Prof. Pickering remarks that ten series of observations of *Polaris*, the photometric magnitude of which he has assumed to be 2·15, were made in order to determine the accordance of successive comparisons made in the same part of the photometric circle. He found the mean discordance of the ten results to be just one-tenth of a magnitude, thus making the corresponding average deviation of the mean of four comparisons ·05. This quantity he assumes to be the average deviation of one set when the comparisons are made at the same part of the circle, or near the same time. Prof. Pickering has also found that the average deviation of one set of four comparisons, at the upper culmination, between *Polaris* and one of the standard circumpolar stars is ·16, and as the mean of the probable errors of the photometric magnitudes determined from all the stars in the catalogue is ·072, and the average number of observations 4·4, the corresponding average deviation is also ·16, thus agreeing with the value obtained from the circumpolar stars alone. Prof. Pickering considers that this deviation of ·16 is due to various causes, the effect of some of which may be separately determined. He has, consequently, deduced an average deviation of ·11, which he attributes to the combination of several causes, such as changes in the instrument or the eye; personal equation between the observers; the uncertainty of the instrumental correction determined from the three observations of *Polaris*; and from the neglect of hundredths of a magnitude in the original computations. He also considers that additional causes may be found in "the variations in the transparency of the atmosphere, actual variations in the light of the stars, undetected errors in identifying the object observed, and mistakes in recording the observations."

Comparing the Harvard results with those of Sir John Herschel's northern and southern sequences, we find the respective differences are ·09 and ·16; with Argelander's magnitudes ·18, with Westphal's ·26, and with Zöllner's ·12. The differences between the Harvard photometric magnitudes of the larger stars in the *Pleiades* and the corresponding values determined by Prof. Pritchard and Lindemann are ·09 and ·14

respectively, and for certain stars compared with variables by Argelander and Schönfeld, ·11 each. Taking 179 stars common to the catalogues of Seidel, Wolff, and the Harvard photometric catalogue, it is found that Harvard differs from Seidel by ·200, and from Wolff by ·120, while Seidel and Wolff differ by ·201. Hence the average deviations of the three catalogues are respectively ·18, ·09, and ·09. These results are in accordance with those found by other methods, and they tend to increase our confidence in the resulting photometric magnitudes of all the separate stars contained in this magnificent contribution to stellar astronomy, with which the name of Prof. Pickering will in future be honourably associated.

It is now time to refer to the corresponding investigation carried on at the University Observatory at Oxford during the last four years, under the able direction of Prof. Pritchard. I believe that I am correct in saying that at the commencement of the observations he was unaware of the methods and intentions of Prof. Pickering, with respect to the system of photometric observations pursued at the Harvard Observatory. Prof. Pritchard's primary object in selecting this branch of research as a fitting one for the new Observatory was the conviction that here an interesting field of inquiry, hitherto to some extent neglected, was open to him. We must, therefore, for our present purpose consider the two investigations as strictly independent and original, and as such they are both recognised by the Council in their award of a joint Medal.

At the meeting of the Society on November 11, 1881, Prof. Pritchard described a simple and practicable method of measuring with considerable accuracy the relative apparent magnitudes of the stars, by means of a new photometer which he had devised, since known as the "wedge-photometer." He, however, claimed no novelty as to the particular implements employed, but only as to the definite methods of applying them and of reducing the results. He had at that time made a photometric comparison of about fifty stars, by which he was assured that far greater precision could be attained in the relative differences of magnitude than by any system of eye-estimation. On May 11, 1883, Prof. Pritchard presented a more elaborate memoir to the Society, entitled, "Photometric Determinations of the relative Brightness of the Brighter Stars North of the Equator" (*Memoirs of the Roy. Astron. Soc.* vol. xlvii.), containing a description of the wedge-photometer, the system of observation, and a statement of the results obtained to the date of publication. The memoir also contains a most interesting historical epitome of all that had been previously accomplished by others in this interesting branch of astronomy, both in the determinations of star magnitudes by photometers of various constructions and also by eye-estimation. The general methods adopted by preceding observers, especially those of Sir William Herschel, Sir John Herschel, and Argelander, are discussed, and the whole

chapter gives a very general notion of the history of the subject. Besides a full explanation of the theory and use of the wedge-photometer, this memoir also includes a photometric determination of the value of the constant of absorption produced by the atmosphere, and notes on the measurement and magnitude of coloured stars, and on the variation of the amount of the extinction of light due to the varying altitude of the star. Although in the Oxford observations the curves graphically representing the variations of brilliancy of the same star at different altitudes were not altogether satisfactory to Prof. Pritchard, he observes that "they did in general represent variations proceeding in accordance with some law, and were fairly consistent until the zenith distance exceeded 60°, but beyond that distance the results were sometimes discordant, and not seldom apparently lawless." So important and essential to his inquiry did Prof. Pritchard consider an accurate knowledge of the value of the absorption constant, that, with his accustomed vigour, he resolved to compare the results of the observations made at Oxford with others determined with the same instrument and observer in some climate steadier and more uniform than that at Oxford. Accordingly, in January and February 1883, we find him, with his assistant, Mr. Jenkins, stationed at the Khedive's Observatory, near Cairo, prosecuting his research with such success that, after a residence of five weeks, no fewer than 3,385 wedge extinctions were made. The absorption constant determined at the two stations, though indicating a real difference of climate, differed less than had been anticipated, the respective values from the Oxford and Cairo extinctions being ·253 and ·187, or ·066 of a magnitude—a quantity about equal to the probable error of an observation with the photometer employed. It may be remarked that Prof. Langley on Mount Etna found the coefficient of absorption to be ·126, Müller at Potsdam ·209, Bouguer in Brittany ·225, and Seidel and Pickering ·250. The corresponding photometric magnitudes determined at Oxford and Cairo are given in the memoir. The measures included in this preliminary synopsis of results are confined to stars brighter than the fifth magnitude of Argelander's scale, and the adopted values are all zenithal magnitudes, the comparison having been made assuming the zenithal magnitude of *Polaris* to be 2·05. The corresponding magnitudes from the catalogues of Ptolemy, Al Sûfi, Argelander, Houzeau, and Gould are inserted for comparison.

This memoir and other shorter communications on the subject have been followed by a more complete work, *Uranometria Nova Oxoniensis*, containing the results of all Prof. Pritchard's photometric observations. Among other kindred works on photometry, this collection of results must take a prominent place, and it will assuredly rank as a standard treatise on the subject, as a reliable exposition of the relative photometric magnitudes of the principal stars visible to ordinary and unaided

eyes from the North Pole to about ten degrees south of the Equator. For the sake of accuracy, I extract from the introduction to this volume Prof. Pritchard's explanation of the construction of the wedge-photometer, with which all his observations have been made. "The wedge-photometer, as employed at Oxford, is a wedge of very nearly neutral tinted glass, $6\frac{1}{2}$ inches long, 1 inch broad, and ·145 inch thick, tapering off to ·02 inch. Cemented to it is a similar wedge of white glass, placed the reverse way; the whole forming a rectangular prism. This glass prism, or *wedge*, is inclosed in a brass cellular rim with bevelled edges, one of which is divided into tenths of inches, the divisions being distinct and white for visibility at night. It slides in a groove on the brass cap of the eyepiece of any telescope, close to the achromatic eye-lens, and is thus placed between the eye of the observer and the telescope. In the focus of the eye-lens is a diaphragm, pierced with a number of small holes, which vary from the hundredth of an inch to a quarter of an inch in diameter, and in which small circular hole the telescope image of a star is carefully placed, and there viewed through the wedge. Further, the eye of the observer is directed along the axis of the lens and of the telescope by means of an external eye-hole, placed close to the wedge, and varying from one-twelfth of an inch to a quarter of an inch. This direction of vision is important. A fiducial mark is drawn on the brass cap of the eyepiece, so that the position of the wedge can be distinctly marked and recorded when the image of the star is just extinguished by the wedge. Usually the position of the wedge, when the light of the star is just extinguished, is observed five times, and the mean of all the five readings is called the *wedge reading*. The extinction of a second star is then observed in a similar manner, and the difference between the two wedge readings is called the *wedge interval*."

It has been customary at Oxford to select about ten stars for one night's work, at nearly the same altitude as the comparison star *Polaris*, so that any correction to the measures for absorption may be avoided. Two telescopes were employed, one of four, the other of three inches aperture, to which photometers were respectively attached. These telescopes being in separate domes, the two observers were each instructed to measure the specified stars independently, taking the precaution to observe the extinction of *Polaris* at the beginning, the middle, and the end of the series. The extinctions of the comparison star were observed five times with the full aperture of the two telescopes, and five times after reducing the aperture to one-half by placing a cap on each object-glass. Thus a check on the first set of five measures was established by means of virtually a new instrument. Then four independent sets of five extinctions were made of each star to be measured, making altogether twenty extinctions. It will thus be perceived that the observations were made in an orderly and systematic manner, and with much simplicity. This

appears to me one of the advantages to be attained by the use of the wedge-photometer.

Prof. Pritchard has ascertained from a special comparison of the means of five extinctions of about twenty stars, made by Mr. W. E. Plummer and Mr. Jenkins, each observing with different apertures the same stars as nearly as possible in point of time, and with the same wedge and telescope, that there is practically no sensible difference of personal equation between the two observers, and that therefore they might safely interchange the instruments without introducing any systematic error in the results.

The 2,784 stars selected for observation are those contained in the *Uranometria Nova* from the North Pole to 10° south of the Equator. The limit of magnitude is therefore Argelander's sixth. In the catalogue the stars are arranged alphabetically in the order of constellations, the separate columns giving the approximate R.A. and N.P.D. for 1890, the adopted zenithal magnitude assuming that of *Polaris* to be 2·05, the average deviation in magnitude, the date of observation, and the corresponding magnitude in the *Uranometria Nova*. Copious notes are given, in which the concluded results for stars observed both at Oxford and Cairo are inserted. We have in this catalogue the relative magnitudes of most of the principal stars visible in the northern hemisphere determined with great precision from upwards of seventy thousand separate extinctions. When we remember that the University Observatory was established under many difficulties, that the observing staff consists of only two assistants, and that during six months of the year much time is given to lecture work and practical instruction to the undergraduates at night, we have strong grounds for giving all the credit that is due to those by whose energy and zeal so much good and standard work has been accomplished since the foundation of this Observatory in 1875.

It is not my desire or intention to make any critical comparison of the results obtained by the wedge-photometer with those derived from other sources. This will probably be done by others at the proper time, and in a more formal manner. But the question naturally arises, are the results obtained by the wedge-photometer to be accepted as fairly accurate representations of the relative stellar magnitudes? Prof. Pritchard considers that they are, as a whole, sensibly accurate to the tenth of a magnitude, and if the probable error be any indication of accuracy, I think he has reasonable grounds for his belief. We have had lately several important discussions at the meetings of the Society on the capabilities of the wedge-photometer, besides other criticisms. Some of these are valuable, especially those of Dr. Wilsing in the *Astronomische Nachrichten*, No. 2,680, but at the same time I believe that the explanations given by Prof. Pritchard in answer to these criticisms have practically smoothed down many of the difficulties pointed out, thus minimising the

effect of some of the systematic errors to which this form of photometer may be liable. Most probably the results derived from every kind of photometer are affected more or less with systematic discordances. I believe there can be no doubt upon this point. But if the deviations from the mean result afford any evidence of the steadiness of observing, it is certainly shown to great advantage in the Oxford observations, though it has been asserted, and not without reason, that the small differences of deviation from the mean is a sign of the want of sensitiveness in the instrument. May we not rather attribute this general agreement partly to the comparatively simple character of the observation, and to the care and attention of the observers? I have been very much impressed on this point by the apparent uniformity exhibited in the tables communicated by Prof. Pritchard to the Society in November last (*Monthly Notices*, vol. xlvi. p. 9), consisting of several nights' repetition of the determinations of the magnitude of sixteen selected stars. These observations were made under different circumstances as regards the condition of the air and the observer. Only in one isolated instance does the difference between the greatest and least daily results exceed four-tenths of a magnitude, while the average deviation from the mean of each of the sixteen stars varies only from ·03 to ·09, or equal to an average deviation of ·06. Referring to the smallness of the discordances, Prof. Pritchard says: "The final results, so far as my powers of scrutiny extend, exhibit no symptoms of systematic error. The average deviation from the mean for all these repeated observations on so many nights still remains approximately the same as for stars measured in the normal manner on a single fair night, viz. about ·06 magnitude; and this, I think, represents in reality the utmost average delicacy attainable with the wedge-photometer, and I claim for it an accuracy at least as great as has been yet attained by any other instrument."

Perhaps it may be considered, and I think very properly so, that one conceivable source of error in the measurement of such minute variations of light might arise from the natural fatigue of the eye during a long series of observations. In order to ascertain whether any error of this kind exists in the Oxford photometric measures, Prof. Pritchard made a special examination of a large number of extinctions of *Polaris* made on separate nights at the beginning, the middle, and the end of each series, from which he appears to be satisfied that there are no real grounds for supposing that any sensible variation in the method of observing, due to fatigue of the eye, takes place during the three hours occupied in making the observations on any one night. From my own personal experience of the ordinary fatigues of a long night's observation with the Greenwich transit-circle, occasionally extending in the winter months over a watch of nine or ten hours, I have invariably found that though at the end of the observations the body may be very

wearied, the eye has usually retained its full sensitiveness, and able to distinguish the faintest objects visible in the telescope equally as well as in the earlier part of the evening. I attribute this apparent retention of acuteness of vision after a long and fatiguing night's work, chiefly to the relief obtained by an occasional rest from observing during the watch, and to the variable work which the eye is called upon to perform during the intervals of actual observation at the telescope. Prof. Pritchard has evidently a similar experience with regard to the Oxford observers, as he finds that any undue strain on the eye is probably compensated by the "relief afforded by continual breaks in the work of actual observation, connected with the shifting of the domes, with the identification of the stars, and with the recording the results." The circumstances of the two cases are not, however, strictly analogous.

It may be a matter of interest to some if I refer to the general agreement existing among the deduced magnitudes of a large proportion of the stars north of the equator common to the Harvard and Oxford catalogues. From a comparison made recently, it is found that the accordances within one-tenth of a magnitude are 31 per cent., within one quarter of a magnitude 71 per cent., and within one-third of a magnitude 95 per cent., leaving only 5 per cent. of discordances exceeding one-third of a magnitude, many of which may be accounted for on reference to the notes. Viewed in this light, and considering that the magnitudes are determined by photometers constructed on totally different principles, we must admit that this general and substantial agreement between the results of the two independent researches is very remarkable, and indicative of a great step having been accomplished towards an accurate knowledge of the relative lustre of the stars.

And now, gentlemen, I have laid before you a short summary of the reasons by which your Council have been guided in the award of a joint Medal for the subject of stellar photometry. In thus recognising the labours of Profs. Pritchard and Pickering, they are glad to acknowledge, at the earliest opportunity, the systematic zeal and devotion displayed by each in the prosecution of their important researches, carried on with an energy which claims our admiration. In Prof. Pritchard we observe an astronomer whose opportunities for stated Observatory work only commenced at a time of life when most of us naturally feel a desire to be relieved from all active research, establishing under difficulties a first-class Observatory, which has already attained a reputation for sound original work, of which many older establishments might well be proud—a reputation that, doubtless, will be retained at least so long as the University Observatory remains under the personal control of our esteemed colleague. We must all congratulate him on the complete success of his labours, in the energetic prosecution of which he has shown himself to be a worthy successor of the long roll of distinguished

Savilian Professors who have preceded him, many of whom are known as honoured and illustrious astronomers, whose investigations form a large portion of the past history of our science. The continuous devotion of Prof. Pickering to astronomical research has also gained for him universal esteem and regard among his associates in astronomy on both sides of the Atlantic, as one of our most original and active inquirers, not only in this branch of the science, the consideration of which has occupied our attention to-day, but also in other important fields of stellar research. By the award of the Medal he is only receiving a due acknowledgment of his valuable services, and a token of the desire of the Council to express their full appreciation of the scientific value of the numerous contributions he has made to astronomy.

The President, on delivering the Medal to Prof. Pritchard and the Foreign Secretary, addressed them respectively in the following terms:—

PROFESSOR PRITCHARD,—

I have very great pleasure in presenting this Medal, which the Council have awarded to you conjointly with Prof. Pickering. I hope you will accept it as an acknowledgment on their part of the excellent work you have accomplished during your superintendence of the University Observatory at Oxford. I assure you that the important contribution you have made to astronomy on the relative magnitudes of the stars is highly appreciated by the Fellows, and I trust that you may still be spared many years to continue your valuable researches.

DR. HUGGINS,—

In forwarding this Medal to Prof. Pickering, I would request you to inform him that the Council entertain the highest opinion on the merits of the important research on which he has been engaged, and for which they have had much pleasure in awarding to him this Medal conjointly with Prof. Pritchard. I trust that what he has so successfully accomplished is only the prelude of further researches, and thus add still more to the great astronomical reputation he has already achieved.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

J. W. L. Glaisher, Esq., M.A., F.R.S.

Vice-Presidents.

J. C. Adams, Esq., M.A., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
The Earl of Crawford and Balcarres, F.R.S.
Edwin Dunkin, Esq., F.R.S.

Treasurer.

A. A. Common, Esq., F.R.S.

Secretaries.

E. B. Knobel, Esq.
Lieut.-Col. G. L. Tupman, R.M.A.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

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J. W. L. GLAISHER, M.A., F.R.S., President, in the Chair.

The Photographic Nebulæ in the Pleiades.

(*Extract from a Letter from M. P. Henry to Mr. Knobel.*)

Nous avons en effet obtenu sur tous nos clichés des *Pleiades*, de faibles traînées nébuleuses près de *Merope*, mais, ainsi que vous pourrez le voir sur la petite épreuve que j'ai l'honneur de vous envoyer, cette nébuleuse ne ressemble en rien à ce qu'en a donné Tempel. Elle a au contraire beaucoup d'analogie avec ce qu'a vu Mr. Common et qu'il a publié en 1882, je crois, dans les *Monthly Notices*.

Dans la petite carte ci-jointe, comme vous pourrez le voir, j'ai un peu accentué à l'aide d'un crayon blanc, les différentes taches lumineuses qui voisinent *Merope*. C'est la réproduction exacte du cliché original. Ces traces nébuleuses sont extrèmement faibles, et ne viennent que fort peu au tirage sur papier.

On peut voir aussi sur l'original une très-faible trace lumineuse partant d'*Electra* et se dirigeant vers l'Est, mais c'est une limite de visibilité, et il ne nous a pas été possible de l'obtenir en moins de 3 heures de pose! Je l'ai indiqué à la craie sur l'épreuve, en l'exagérant, bien entendu.

J'avais l'intention avant d'envoyer à la Roy. Ast. Soc. une carte complète des *Pleiades* avec la nébuleuse de *Merope*, d'essayer d'obtenir cette dernière un peu plus intense s'il avait été possible, mais malheureusement le temps n'a pas été suffisamment beau, et nous devrons nous en tenir, jusqu'à l'année prochaine du moins, à ce que nous avons déjà.

Note on some recently published Spectroscopic Observations.

By E. W. Maunder.

There have been published recently three series of spectroscopic observations to which I should like to draw the special attention of the Society, as each in its own department is of considerable novelty and importance, and it seems to me that it is, on that account, very desirable that they should not take their place among the accepted facts of science without a thorough and searching criticism. It may seem ungracious thus to challenge definite and positive observations; but I need scarcely say that I have not the smallest idea of calling in question the good faith of the observers. My only wish is to draw such attention to the observations referred to as may result in the publication of further details respecting them, or in inducing other observers to make such further researches in the same directions as may confirm or discredit those before us. I am aware that it is not very usual for papers read before the Society to be of a merely critical character; but if the present Note should lead to the bringing out of further and more decisive results, I do not think it will have been useless.

I. Bright Lines in Stellar Spectra. Mr. O. T. Sherman. *Science*, vol. vi., pp. 262, 336, and 386; *Amer. Jour. of Science*, vol. xxx. pp. 378 and 475; *Astronomische Nachrichten*, Nos. 2707 and 2709.

The first series of observations to which I would ask attention is the detection of bright lines in stellar spectra, by Mr. O. T. Sherman, of Yale College Observatory. The first published observation by Mr. Sherman appeared in the number of *Science* for September 18, 1885, and described the detection of certain bright lines in the spectrum of *Nova Andromedæ*. A second communication furnished the positions of these lines, and I was naturally much gratified to find that Mr. Sherman's determinations agreed with the rough estimations I myself had made, in a manner which was really remarkable when the difficulty of the observation was borne in mind. Mr. Sherman has since examined the spectra of many other stars, beginning with β *Lyræ* and γ *Cassiopeiæ*. In these two he found not only the bright lines of hydrogen usually seen, but a number of other bright lines, corresponding apparently to the principal lines of the solar chromosphere. In all seventeen bright lines were detected in the spectrum of β *Lyræ*.

So far, though Mr. Sherman's results were both interesting and striking, there was nothing on the surface to provoke scepticism. The two stars in question are known to have certain bright lines in their spectra, and it might well be that an observer might detect fresh ones, either by the aid of a special equipment, or by means of an exceptionally keen sight. But Mr. Sherman

has since examined the spectra of some fifty other stars, and his report upon them is that "in *each* case many or few bright lines have been seen." It is clear that if this statement can be substantiated, we have here an advance in stellar spectroscopy of the most important character. The question naturally arises as to what was the instrumental means at the observer's command?

The telescope employed had an aperture of 8 inches; the spectroscope was a direct-vision one, with two sets of prisms, three in each set. With one set of prisms b_3 and b_4 are barely separated; with both sets the nickel line between D_1 and D_2 is seen. The collimator is about six inches long, and "the power of the eyepiece of the observing telescope is about 130," meaning, I suppose, the power which the eyepiece would have if used on the Equatorial telescope of 8-inch aperture, and not the power it would have when taken in conjunction with the viewing telescope of the spectroscope alone.

So far there seems little ground for criticism; the instrument, if not specially powerful, would seem fairly suited to the work; but there seem some points in Mr. Sherman's further account of his method which, if I rightly interpret them, indicate, I would venture to think, a faulty procedure.

First: "previous to each night's work the instrument was adjusted upon the Sun; a solar spot, when possible, being brought sharply in focus upon the jaws of the slit." This would seem a proper and necessary adjustment, and would suffice for the centre of the spectrum; but for the extreme rays, especially the blue and violet, the spectroscope would not be in the proper focus of the equatorial. There is a paragraph in Mr. Sherman's paper which at least suggests that the extreme ends of the spectrum suffered from maladjustment in this way: "At the red end under a sharp focus they" (the bright lines) "stand out the full breadth of the spectrum, bearing somewhat the same relation to the background as the prominence to the solar spectrum. In the brighter portion of the spectrum they are cut down to fine star-points. At the blue end they become more distinct, but not so sharp as at the red. At times they shine with almost a metallic brilliancy; at other times they are faint, faded, and easily passed over. Certain sets appear to be prominent at times, others at other times."

It seems very difficult to believe that this can be a description of the behaviour of true stellar bright lines, while it is quite conceivable that lines due to some instrumental defect might present just such an appearance in a spectroscope adjusted, as Mr. Sherman's seems to have been, only for the centre of the spectrum, particularly as he placed his cylindrical lens, not before the slit, nor even in the viewing telescope, but between the eyepiece and his eye.

Secondly: Mr. Sherman used an unusually wide slit, "5^{mm} or more." I think most stellar spectroscopists will pronounce

this to have been fully 100 times too wide. 5^{mm} in the focus of the 8-inch object-glass would correspond to 6′ of arc. It seems hard to see what purpose a slit of so great a width would serve, and in what essential feature it differed from no slit at all. And it is also difficult to place much confidence in measures made with so wide a slit, especially as the collimator only measured 6 inches in focal length, so that no stress can be laid upon the correspondence between the bright lines observed, and those seen in the solar chromosphere.

The most suspicious circumstance of all, however, is, I think, that so far Mr. Sherman has never failed to see bright lines in any star which he has examined; and that though "sometimes they shine with almost a metallic brilliancy," yet no previous observer has ever detected them.

My experience of bright lines in stellar spectra has been limited to γ *Cassiopeiæ*, and perhaps *Nova Andromedæ*. But I have had occasion to notice on more than one occasion that a stellar spectrum which is full of dark lines or bands may, when badly seen, give a very perfect illusion of bright lines; the dark lines escaping recognition as such, but producing their effect by making the parts of the spectrum most free from them shine out by contrast like a veritable chromospheric spectrum. I have also, in my measures of the displacement of lines in stellar spectra, used on some 100 stars a dispersion considerably greater than Mr. Sherman's, the very greatest, in fact, the star would bear, without bringing up the faintest trace of a bright line; so that I cannot put down my own failure to detect these lines to insufficient dispersive power.

Since I commenced to draw up this note, Prof. Vogel has criticised* Mr. Sherman's observations in the *Astronomische Nachrichten*, on grounds which closely correspond to some of those which I have here brought forward; but he mentions in addition the mistake which Secchi fell into with regard to the spectrum of *Sirius*: an instance which shows how readily even an experienced spectroscopist may be made the victim of an instrumental illusion.

II. Observations of the Spectrum of *Nova Orionis*. Dr. Ralph Copeland. *Monthly Notices*, vol. xlvi. No. 3.

In venturing to criticise Dr. Copeland's paper on the spectrum of the new star near χ_1 *Orionis* read before this Society at the January meeting, I have not the smallest intention of calling in question the observations themselves. These are undoubtedly very accurate; the only point open to question is the interpretation to be put upon them. There is no doubt as to the general appearance of the spectrum. It resembles the spectra of Secchi's third type, of which α *Orionis*, α *Herculis*, *Mira Ceti*, and β *Pegasi* are amongst the best known examples. But the contrasts of

* *Astron. Nachr.* No. 2712.

light and darkness are unusually pronounced, so that it becomes a question whether we ought to regard the spectrum as consisting of a brilliant continuous spectrum crossed by intensely dark bands, or of a feeble continuous spectrum, with vivid bright bands superposed upon it. It is, in fact, a somewhat similar question to that raised by Dr. Henry Draper with regard to the existence in the solar spectrum of bright lines due to oxygen. Hitherto all observers seem to have preferred the former view; Dunér,* Riccò,* Thollon,† Trépied,‡ Vogel,§ and Wolf,‖ however much inclined on a first view to believe in the presence of bright lines, all agreeing on more careful scrutiny to see in the spectrum of the new star but an unusually fine example of the third type, showing no very essential points of difference from that, for example, of *α Orionis*. Dr. Copeland, on the other hand, considers that "the spectrum is not so much a continuous one, interrupted by dark lines and dusky bands, as *a not very luminous spectrum upon which a series of bright bands are superposed.*" Further, he identifies some of these bands, as those so well known to us as characteristic of hydro-carbon and of cometary spectra.

Of the importance of this view, if it can be substantiated, there can be no doubt. We cannot confine it to a single member of the type, but must regard *all* the stars of Secchi's third group as possessing a similar constitution. For the characters and positions of the bands are practically the same throughout all the members of the group; the only difference being in their comparative intensity. And in this respect we have every conceivable gradation from the bold and beautiful contrasts of the present star and of *α Herculis*, *ρ Persei*, *Mira Ceti*, and others, down to stars in which they can only just be detected. Further, many of the stars being variable, the intensity of the contrasts often varies from time to time in the same spectrum; so that there is no possibility of drawing a line, and saying, "These stars have bright bands on a feeble background, and the others dark bands on a bright background." The verdict passed on *Nova Orionis* must be passed on all the members of the same type.

The hypothesis is certainly a tempting one. Seeing that we possess spectra intermediate in character between a true solar and a pure banded type, we might, on the one hand, well be tempted to push Dr. Draper's views a little further, and see not only bright oxygen lines in some of the clear interspaces of the solar spectrum, but to find in others traces of hydro-carbon bands; while, on the other hand, the red stars plainly show an absorption spectrum corresponding to the hydro-carbon bands; so that the spectroscopic chain connecting together comets and the various orders of stars would be complete.

* *Astron. Nachr.* No. 2707.
† *Comptes Rendus*, vol. cii. No. 7
‡ *Ibid.* vol. cii. No. 1.
§ *Astron. Nachr.* No. 2704.
‖ *Comptes Rendus*, vol. ci. No. 26.

But there are several difficulties in this view. First, the dark bands of spectra of the third type must be regarded as true absorption bands, and not merely as traces of a very feeble continuous spectrum appearing dark only by contrast with the vivid bright bands superposed upon it, for under favourable circumstances they have been resolved into separate fine lines; and M. Wolf believes that he has been able so to break up the bands in the spectrum of *Nova Orionis* itself. And, secondly, though at present we are unable to draw any particular inference from the fact, it can hardly be a chance coincidence that in each case the more refrangible edge, the sharp dark edge of these bands, agrees in position with some well-marked metallic line, usually with one ascribed either to iron or calcium.

Then, further, the districts of the spectrum which Dr. Copeland considers to be bright bands correspond in every case to districts which, in other spectra of the type, are simply free from absorption bands or lines. Line by line, band by band, every object Dr. Copeland has considered as a bright line or band corresponds with what in other spectra are simply regarded as clear spaces; the only difference is the somewhat greater comparative brilliancy of these spaces in *Nova Orionis*. Undoubtedly if the continuous spectrum be very bright, and the absorption bands very dark, these spaces very greatly resemble bright lines in appearance. They do so in α *Herculis*, ρ *Persei*, and several others when viewed with small dispersion, but the illusion promptly disappears when a great dispersion is employed. And in the particular instance before us, M. C. Wolf records that, though the *Nova* seemed at first to present bright lines in the blue and green, with greater dispersion he could not establish the presence of a single line.*

Further, the coincidence of Dr. Copeland's bright lines and bands with those of the hydro-carbon spectrum is by no means exact. The positions of these bands are now known with great exactness, the different investigators who have determined them agreeing very closely indeed in their results. In all, five of these bands have been detected in the spectra of comets; two of them, the red and violet, having been only rarely seen. But the other three have been frequently seen, and their exact coincidence with the bands of the hydro-carbon spectrum placed beyond dispute. The brightest band is the one in the green, wave-length, according to Thalén,† 5164 tenth-metres. Dr. Copeland identifies this with the bright space immediately following the sharp dark edge of what I have called the dark band VI.‡ But numerous and repeated observations have shown that the edge of this band coincides with the magnesium line b_4, the wave-length of which is 5167. The difference is indeed too small to be detected easily with such dispersion as *Nova Orionis* would bear,

* *Comptes Rendus*, vol. ci. No. 26.

† Angström and Thalén, *Recherches sur les Spectres de la Métalloides*.

‡ *Monthly Notices*, vol. xlvi. p. 114.

but the positions both of the carbon band and of the magnesium line have been determined with far too great a degree of accuracy for the difference to be due to errors of observation. Dr. Copeland is confirmed in his view that this bright space is the green hydro-carbon band by finding a second line at λ 5137. A reference to Huggins and Miller's * drawings of the spectra of *α Orionis* and of Aldebaran at once explains the origin of the second line. The bright space is interrupted here by a strong dark line, ascribed by Dr. Huggins to bismuth. Dr. Copeland's measures, too, scarcely support his view. The wave-length of the hydro-carbon line is 5128; the values Dr. Copeland obtains for his bright line are 5157, 5131, and 5124.

The second band in order of brightness in the hydro-carbon spectrum begins at λ 5634. This is certainly non-existent in spectra of the third type, a broad dark band,—No. 4 in Dunér's nomenclature and my own, wave-length 5642 to 5592,†—occupies the very place. The third hydro-carbon band, that in the blue, with wave-length for its less refrangible edge 4737, is indeed not far from the bright space Dr. Copeland has observed at λ 4722, but the correspondence is certainly not very exact. But whilst the bright spaces in the spectrum of the star answer so very imperfectly to the hydro-carbon bands, the hydro-carbon bands correspond still worse to the bright spaces. As Dr. Copeland himself points out, the spaces at λ 5428 and λ 4944 correspond to no known hydro-carbon band; and there are, besides, bright lines or bands at λ 6110, λ 5841, λ 5771, λ 5592, λ 4923, and λ 4778 to find an explanation for, if the natural one, hitherto accepted, that they are simply the clear intervals between dark absorption bands, be set aside.

III. Les changements temporaires de réfrangibilité des raies du spectre de la chromosphère et des protubérances solaires. M. E. L. Trouvelot.—*Bulletin Astronomique*, January 1886.

The third series of observations of which I wish to speak are contained in a paper by M. Trouvelot in the January number of the *Bulletin Astronomique* on temporary changes of refrangibility of the lines of the spectrum of the solar chromosphere and prominences. Eight remarkable observations are very fully described, and illustrated in a series of 22 diagrams. The observation to which I would more particularly allude is the fifth, which is to the following effect:—M. Trouvelot was examining the limb of the Sun on June 26, 1874, when he found at 270° several eruptive jets, above which floated a brilliant prominence, with an apparent height of 3′ 37″. Observed with the slit opened sufficiently wide to admit the entire prominence between its jaws, the prominence resembled an immense fiery comma. But with a

* *Phil. Trans.* 1864, plate xi.

† Dunér, *Les Etoiles à Spectres de la Troisième Classe.*

narrow slit *this prominence was projected whole on the spectrum on the side towards the red, and advanced upon it for its full height to a distance from the C line eight-and-a-half times the interval between the D lines.** The diagram represents the prominence as being wholly unchanged in size and appearance, whether observed through a slit opened so widely as to admit the entire prominence between its jaws, or through a slit so nearly closed that the lowest point of the prominence was well outside it. Finally, after having been attentively watched for some minutes, "it disappeared with the instantaneousness of a flash of lightning."

I mention this observation particularly because it seems to me that, if accepted, it must entirely modify our views as to the displacement of spectral lines indicating motion in the line of sight. M. Trouvelot infers from his observation that the prominence was receding with the incredible speed of 2584 km. per second. The observation involves much more than this. Had this been all, he would simply have noted a bright line, no wider than his narrow slit, situated far down the spectrum, at the point to which the extreme tip of the prominence seemed to reach. Displacements of this character, but of a much smaller amount, have often been witnessed. But what was witnessed in the present case was something very different. The "prominence," so called, extended *nearly continuously* from C to a distance of more than eight times the interval between the D lines from it, and was therefore, according to the diagram, more than twenty times as wide as the C line. If this increase in breadth and change of refrangibility was due solely to motion of the solar gas streams, it would mean, not that the part of the chromosphere under the slit was moving at the rate of 2584 km. per second, but that it was moving with every conceivable velocity from rest up to that amazing speed. The curious convolutions shown in the shape of the prominence would imply a yet greater complexity and intricacy in the movements of the gases under observation. At certain points of the limb the gases must have been moving with two or three separate ranges of velocities—say, to speak roughly, from 1,000 to 1,500 km. per second, and also from 2,000 to 2,500 km. per second, but with no velocity intermediate between these ranges. It does not seem credible that this state of things can possibly have a real existence.

M. Trouvelot records that the prominence disappeared like "a flash of lightning." He explains this disappearance as due to the prominence being carried round the limb of the Sun by its rapid motion. But, as justs hown, the bulk of the prominence was not moving with the extreme velocity noted, 2,584 km. per second, but with every conceivable smaller velocity. What ought

* *Observée avec la fente plus étroite, cette protubérance se projetait en entier sur le spectre du côté de l'extrême rouge, et s'avançait sur lui de toute sa hauteur, jusqu'à une distance de la raie C égale à huit fois et demie l'intervalle* Δ."

to have happened, therefore, was that it should have died away from its summit downwards, diminishing in brightness the while.

It should also be remembered that these velocities as referred to the Sun are not velocities of eruption in the radial line, but velocities tangential to the surface. If such movements take place in the chromosphere in the direction of the line of sight, movements similar in character should also be noticed from time to time in the direction perpendicular to that line. Hitherto, certainly, no such speeds have been witnessed. The displacements, on the contrary, which Lockyer and other observers have placed on record indicate movements which are essentially of the same order of velocity as those determined by direct observation.

M. Trouvelot mentions several other observations, only less remarkable than the one to which I have drawn attention, from which similar conclusions may be drawn. It is to be earnestly hoped that he will not hesitate to publish in the fullest detail all that he has made which bear upon the subject, and that other solar spectroscopists will do so likewise, since it seems clear that if there is nothing radically wrong in these observations, it will be no longer safe to deduce the rate of motion in the line of sight from observations of displacements in the prominence and chromospheric lines, but that we must look for their explanation to molecular motion within the gases themselves—a direction which has hitherto been scarcely regarded as admissible.

Additional Remarks on the Periodic Time of α Centauri.

By E. B. Powell.

I wish to offer some further remarks in connection with the suggestion I made in No. 1 of the *Monthly Notices* for 1884–85, to the effect that the period of *α Centauri* may be considerably longer than has generally been supposed. I agree with Mr. Downing that the test of a theoretical orbit is its standing comparison with observation; but then this test should be applied to the *whole* circuit of the comes round its primary. While a portion of the orbit is left unchecked by trustworthy observations, it is quite possible that a certain ellipse may fairly satisfy recorded measures and yet prove to some extent erroneous. In the case of *α Centauri*, the true orbit is so disguised by the manner in which it is presented to our view, that more than one perspective ellipse may be found which will agree tolerably well with recorded measures; and, if we desire to anticipate the future, when the motion round the south preceding end of the orbit will be accurately fixed by equatorial observations and the correct elements become evident, we must take note of every indication, however imperfect, which may help us to forecast the character of the path. It appears to me also that, in an instance such as the one under consideration, where the number of degrees

to be described for the completion of the circuit is small (about 17°), it is not sufficient to compare position-angles, especially as those representing observation are derived from differences of Right Ascension as well as from differences of Declination, and the errors of the former may be considerable. I think that a more satisfactory mode of testing the orbit for that portion is to find from the theoretical ellipse the differences of Declination of the components at the particular epochs and to compare these with the observed differences of Declination. Following this view, I have drawn up the following table, in which are given the differences of Declination of the several observers and those afforded by the Downing-Elkin orbit, undoubtedly the best hitherto published.

Observer.	Epoch.	Observed Diff. of Dec.	Diff. of Dec. sec. Downing-Elkin.	Obs. Diff. Dec. −Theoret. Diff. Dec.
		″	″	″
Henderson	1833·0	14·82	14·65	+ ·17
Johnson and Taylor	1832·15	15·98	15·07	+ ·91
Rümker	1827·0	19·54	17·10	+2·44
Dunlop	1826·0	18·79	17·38	+1·41
Fallows	1823·0	25·00	17·96	+7·04

In connection with the table it will be well to make a few remarks.

Henderson's measure scarcely needs a comment; it is derived from 27 observations of a_1 and 29 of a_2, taken towards the end of 1832 and the beginning of 1833.

In the case of Johnson and Taylor it seemed advisable to take the mean of their measures. The observations of the former gave diff. of Dec.=16″·2 for 1831·94, and those of the latter, diff. Dec.=15″·77 for 1832·37; the mean is entered in the table.

In Rümker's Paper in the *Phil. Transactions* for 1829 some of the measures are useless for the present purpose, owing to one component alone having been observed during the early years of Sir Thomas Brisbane's Observatory. But taking the observations for the last months of 1827, in which both components are included, we have diff. Dec.=21″·2 for a date which may be taken approximately as 1828·0. It is, however, to be noticed that, while a moderately large number of measures were taken of a_2, of a_1 there were only four, and that the maximum difference of the latter was as 6″·3. In Rümker's "Preliminary Catalogue," published at Hamburg in 1832, in which he compares his own and Lacaille's measures, the diff. Dec. of the former is put down as 19″·54; the accompanying remarks made by him, and a consideration of the dates on which he joined and left the Brisbane Observatory, render it probable that the epoch corresponding to the above value is 1827–28. It seems not improbable that 19″·54 was a final, and in Rümker's eyes a presumedly more accurate value than 21″·2. I have accord-

ingly adopted this value; and I have assigned it to 1827, though perhaps it belongs rather to 1828; the assignment of it to 1828 would render the value of {observed diff. Dec.—diff. Dec. by the Downing-Elkin orbit} greater than that entered in the table.

Dunlop's diff. of Declination may be assigned to 1826·0.

On examining the note-books and other MSS. on which Richardson's Paramatta Catalogue is based, which the Assistant Secretary was kind enough to place before me, I found they supported the view that there were no measures taken of *both* α_1 and α_2 *Centauri* before the end of 1825 or beginning of 1826; and I came to the conclusion that, for the present purpose, no notice need be taken of the Catalogue, the results therein contained being simply Dunlop's measures, which are given, slightly modified, in his papers in the Society's *Memoirs*.

Fallows' diff. of Dec. must be considerably too large. This is rendered evident by finding the sectorial areas for the intervals between his epoch and those of subsequent observers. It is, of course, impossible to say what amount of error attaches to his diff. Dec., but it seems likely that the error reaches some 4″ or 5″. The circumstance is not surprising, since his telescope did not separate the close components of α *Crucis*, which are about 5″ distant from each other. At the same time it is to be remembered that Fallows was a remarkably careful observer; and it would be a mistake to attribute to him an error to which the inferiority of his instrument did not render him liable.

It appears from the table that concurrent testimony is borne by all the observers, from Henderson backwards, that the differences of Declination afforded by the Downing-Elkin orbit are too small. In fact, the largest diff. of Dec. which that orbit will admit of is about 18″; while, judging from recorded observations, the diff. may be supposed to reach some 20″. From this it seems to follow that the periodic time must exceed seventy-six years; and then, having regard to Feuillée's important observation in 1709, discussed in my former Paper, it appears probable that the period of α *Centauri* extends over eighty-six, or more, years.

Hampstead:
1886, *March* 3.

On the Orbit of 40 (o^2) *Eridani.* By J. E. Gore, M.R.I.A.

The star 40 (o^2) *Eridani* with its distant double companion forms a remarkable ternary system. As far as I know, the elements of the orbit have not hitherto been published. The close pair B C have described over 200° of its apparent ellipse since it was measured by Sir W. Herschel in 1783. By means of the graphical method described in the *Handbook of Double Stars* by Messrs. Crossley, Gledhill and Wilson, I have computed the orbit, and find the following elements:—

Elements of 40 Eridani (BC).

P = 139·0 years.	Ω = 146° 20′ (1880·0).
T = 1863·88.	λ = 354° 23′.
e = 0·1362.	a = 5″·99.
γ = 76° 20′.	μ = −2°·59.

From these elements we have the following formulæ:—

(1) $u - 7{\cdot}80 \sin u = -2°{\cdot}59$ (t = 1863·88),

(2) $\tan \frac{1}{2}V = 1{\cdot}146 \tan \frac{1}{2}u$,

(3) $\tan (\theta_c - 146° 20') = 0{\cdot}23627 \tan (V + 354° 23')$,

(4) $\rho = 5''{\cdot}99 (1 - 0{\cdot}1362 \cos u) \dfrac{\cos (V + 354° 23')}{\cos (\theta_c - 146° 20')}$;

where u is the eccentric anomaly, and V the true anomaly for any epoch t, θ_c the position-angle, and ρ the distance.

The following table shows a comparison between the recorded observations and the positions computed by the above formulæ. The computed angles have been corrected for the effect of precession.

40 *Eridani (BC).*

Comparison of Observations with Elements.

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	′ ″	″	″
1783·13	Sir W. Herschel	326·7	329·93	−2·23	4−8	6·41	—
1825·12	Struve	287	292·28	−5·28	—	—	—
1850·94	O. Struve	156·6	156·56	−0·04	3·96	4·29	−0·33
1851·06	Dawes	160·0	156·44	+3·56	3±	4·29	—
1851·49	O. Struve	155·0	155·96	−0·96	3·87	4·37	−0·50
1853·64	„	155·4	153·67	+1·73	3·93	4·66	−0·73
1854·79	„	155·3	152·55	+2·75	4·13	4·78	−0·65
1856·80	„	152·9	150·73	+2·17	4·51	4·97	−0·46
1857·82	„	153·0	149·84	+3·16	4.40	5·03	−0·63
1864·80	Winnecke	147·6	144·18	+3·42	4·45	5·12	−0 67
1864·84	O. Struve	147·6	144·18	+3·42	4·45	5 12	−0·67
1865·89	„	143·8	143·28	+0·52	4·26	5·03	−0·77
1869·10	„	140·4	140·24	+0·16	4·46	4·79	−0·33
1872·56	„	140·6	136·86	+3·74	4·62	4·35	+0·27
1873·99	„	133·9	135·13	−1·23	4·27	4·09	+0·18
1874·10	„	135·7	135 02	+0·68	4·99	4·11	+0·88
1875·14	„	138·1	133·6	+4·5	3·80	3·89	−0·09
1877·84	Cin. Obs.	127 5	129·34	−1 84	4·36	3·43	+0·93
1877·86	Burnham	128·2	129·34	−1·14	3·92	3·43	+0·49
1879·05	„	125·4	127·0	−1·60	3·66	3·22	+0·44
1880·09	„	121·3	124·5	−3·2	3·28	2·99	+0·29
1880·95	„	122·0	121·5	+0·5	3·16	2·74	+0·44
1881·84		119·0	119·7	−0·7	3·53	2·62	+0·91
1883·00		119·2	115·6	+3·6	3·07	2·39	+0·68

The elliptical motion is, of course, probably somewhat perturbed by the attraction of the principal star, which, though very distant, is much larger, its apparent magnitude being about $4\frac{1}{2}$, while the components of the binary pair are 9 and 10·8.

Assuming the above elements, and the parallax of the star at 0″·223 (as found by Prof. Asaph Hall), I have computed the following figures, which may be of interest.

Taking the Sun's mean distance from the Earth as unity, I find

Distance of 40 Eridani from the Earth	924955
Mean distance between the components, B C	26·86
Sum of masses of B C / Sun's mass = 1	1·003

Some new Red and Orange-red Stars. By the Rev. T. E. Espin.

The observations of the stars were made with a 9-inch Calver Reflector equatorially mounted, and with a $17\frac{1}{4}$-inch Calver reflector, equatorially mounted also, with driving clock, and circles reading in R.A. to 5 seconds, and in Declination to 1′. Since September 24 the observations were made with the latter instrument. The power used was a sweeping power of 70. The first column gives the number continued from the list given in vol. iii. *Liverpool Astronomical Society's Journal*, p. 82; the second, the D. M. number; the third the approximate R.A. and Declination brought up to 1885; the fourth, Argelander's magnitude; the fifth and sixth, the observed mean magnitude and colour; the seventh, the number of nights on which each star was observed; the eighth, the night it was detected. An asterisk denotes that the star was previously observed by my friend, the late Rev. T. W. Webb. Certain orange stars have been included, either because they are finely coloured, or because of a neighbouring blue star—a combination of frequent occurrence, the reason of which is at present unexplained. Mr. Webb's observations, and my own, where there seemed any reason for giving them in detail, will be found in the notes.

Abbreviations: RR, very red; R, red; R^1, pale red; R^2, very pale red. Shades of orange-red and orange denoted in the same way, by ORR, &c., and O.

No.	D.M.	R.A. 1885.	Decl.	Magnitude. Arg.	Obs.	Colour.	No. of Nights Obs.	Date. 1885.
	°	h m	° ′					
33	54·116	0 30·6	+54 35·6	7·8	8·5	R^2	1	Dec. 4
34	39·167	38·3	+40 3·0	7·1	7·0	OR^2	3	Oct. 1
35	57·258	1. 12·5	+57 42·3	8·8	8·5	R	3	Dec. 2

No.	D.M.		R.A. 1885.	Decl.	Magnitude. Arg.	Obs.	Colour.	No. of Nights Obs.	Date.
	°		h m	° ′					1885.
36	57·320		25·7	+57 48·2	6·5	6·0	OR¹	1	Dec. 2
37	60·327		37·8	+60 27·2	8·5	8·5	RR	1	Dec. 2
38	60·335		38·2	+60 24·8	9·4	9·5	R¹	1	Dec. 2
39	59·466	II.	11·3	+59 29·0	6·7	6·6	O²	2	Dec. 2
40	58·445		12·0	+59 8·1	8·8	8·5	R	2	Dec. 2
41	52·637		43·6	+52 32·4	7·0	7·5	OR²	1	Nov. 16
42*	24·570	III.	41·2	+24 37·9	7·0	var.?	OR¹	2	Nov. 5
43*	25·599		50·6	+25 9·4	6·8	7·0	O²	1	Nov. 17
44	2·640		57·3	+ 2 44·4	7·8	6·5	OR¹	1	Dec. 7
45	12·547		57·9	+12 11·2	7·7	7·5	R¹	1	Dec. 9
46	34·863	IV.	14·0	+34 17·6	7·5	8·0	OR	1	Nov. 30
47	34·874		16·8	+34 58·7	7·2	8·0	OR¹	1	Nov. 30
48	6·865	V.	5·9	+ 6 42·7	7·9	7·8	R	1	Dec. 16
49	45·1084		9·3	+46 0·0	7·8	var.	OR¹	7	Oct. 9
50	35·1046		11·5	+35 40·0	8·9	8·5	RR	3	Nov. 20
51*	—		12·5	− 8 22·2	—	8·5	ORR	1	Dec. 7
52	29·897		19·8	+29 49·2	8·0	8·0	RR	3	Nov. 14
53	—		19·6	−10 27·2	—	6·0	OR¹	1	Dec. 7
54	32·1030		26·2	+32 39·8	7·0	6·5	OR²	2	Nov. 17
55	50·1225		38·3	+50 2·4	7·1	7·0	OR¹	1	Nov. 30
56	44·1288		40·2	+44 47·9	9·2	8·6	RR	8	Nov. 5
57	32·1109		44·0	+32 5·7	6·6	6·0	OR	1	Nov. 16
58	53·962		46·3	+53 26·1	8·0	8·2	R	2	Nov. 17
59	54·971		50·3	+54 32·6	7·0	7·0	O¹	2	Nov. 17
60*	44·1331		51·6	+44 58·9	8·1	8·0	O²	2	Oct. 24
61	28·966		52·8	+28 7·0	6·9	7·5	O²	2	Nov. 14
62	33·1290	VI.	9·9	+33 14·9	9·1	8·5	RR	2	Dec. 13
63	Anon.		41·5	+ 0 48·4	—	9·6	RR	4	Dec. 14
64	—		51·0	− 3 2·4	—	8·0	R	1	Dec. 16
65	—	VII.	11·8	−23 6	—	7·0 var.?	O	1	Dec. 1
66	54·1337	IX.	48·5	+54 48·2	7·0	7·5	OR¹	1	Dec. 13
67	27·2509	XV.	29·7	+26 54·6	8·2	8·0	R¹	4	June 30
68*	24·2901		33·3	+24 53·8	7·4	7·0	OR¹	1	June 30
69	35·2828	XVI.	26·8	+35 28·7	7·0	6·0	OR²	2	June 30
70	35·2911		59·4	+35 34·2	6·5	6·5	OR²	2	June 30
71	14·3201	XVII.	6·7	+14 38·3	7·3	7·0	O¹	1	July 13
72	17·3213		12·8	+17 14·3	7·5	8·0	O	1	July 13
73	17·3225		15·6	+17 10·2	7·8	7·0	R¹	1	July 13

No.	D.M.		R.A. 1885. h m	Decl. ° ′	Magnitude. Arg.	Obs.	Colour.	No. of Nights Obs.	Date. 1885.
74	12°3256		30·5	+12 6·6	7·0	7·0	R²	1	July 9
75	35·3006		30·6	+35 57·1	7·5	7·8	OR²	2	June 30
76	36·2937		42·8	+36 7·5	6·5	6·7	OR²	2	June 30
77	36·2942		43·9	+36 35·7	6·5	6·7	R²	2	June 30
78	12·3305		45·3	+11 59·4	6·4	7·0	O¹	1	July 9
79	1·3524		46·2	+ 1 8·2	6·8	7·5	R²	1	July 8
80	1·3528		46·7	+ 1 20·5	6·0	7·0	R¹	1	July 8
81	17·3520	XVIII.	12·7	+17 55·4	7·5	7·0	R²	1	July 13
82	38·3219		30·2	+38 20·9	7·3	7·0	OR	1	Sept. 25
83*	37·3180		33·6	+37 40·8	7·0	6·5	R²	3	June 30
84	44·2961		37·3	+44 51·7	8·6	8·5	R²	1	July 25
85	44·2969		38·8	+44 51·6	9·1	9·0	R²	1	July 25
86*	39·3505		39·4	+39 11·1	6·5	7·0	OR	1	July 23
87	36·3339		53·1	+36 18·9	7·0	7·0	OR¹	1	June 30
88	23·3543		58·8	+23 10·8	8·0	8·5	R²	2	July 2
89	38·3445	XIX.	4·3	+38 58·4	6·9	7·7	O²	3	July 8
90	38·3493		10·0	+38 46·5	7·7	7·7	OR²	3	July 4
91	38·3518		13·2	+38 46·6	6·7	6·9	R²	1	June 30
92	37·3403		13·5	+37 23·8	8·0	8·0	R²	2	June 30
93	17·3940		16·5	+17 26·4	9·5	var.	RR	3	Sept. 27
94	49·2999		21·5	+50 0·4	7·5	7·0	R¹	2	July 5
95	9·4114		23·0	+ 9 23·6	8·1	8·0	OR¹	3	July 8
96	25·3884		30·4	+25 44·9	8·2	8·3	OR²	6	July 5
97	23·3706		31·0	+23 35·7	8·0	8·0	R¹	1	July 4
98*	17·4043		35·0	+17 37·7	8·2	8·0	O²	2	July 20
99	37·3577		38·7	+37 24·8	7·9	8 0	OR²	4	June 30
100*	−0·3386		39·6	− 1 1·7	9·3	8·0	O	1	Sept. 25
101	40·3866		40·1	+40 25·9	6·3	6·0	OR	1	July 23
102	10·4046		41·1	+10 10·8	8·3	8·0	OR²	3	July 8
103	35·3784		41·2	+35 47·7	9·1	9·5	R²	2	July 2
104*	9·4264		42·4	+ 9 45·2	8·1	8·0	O¹	2	Sept. 24
105	38·3780		46·4	+38 25·5	5·5	6·0	O	1	July 23
106	37·3636		46·6	+37 31·4	7·0	7·0	R²	2	June 30
107	25·4006		47·5	+25 40·0	8·5	8·5	OR	2	Oct. 5
108	44·3295		53·5	+44 44·5	9·0	8·0	R²	1	July 25
109*	17·4185		54·9	+17 17·5	7·5	7·5 var.?	R¹	1	July 9
110*	37·3744		59·5	+38 0·1	7·2	8·5	R²	2	July 12
111	14·4209	XX.	5·2	+14 12·4	7·5	8·0	O²	1	Sept. 27

No.	D.M.	R.A. 1885.	Decl.	Magnitude. Arg.	Obs.	Colour.	No. of Nights Obs.	Date. 1885.
	°	h m	° ′					
112	38·4003	14·8	+38 38·4	6 8	7·0	OR^2	2	July 12
113	39·4130	14·5	+39 52·1	8·0	8·0	OR^1	1	Oct. 1
114	39·4152	17·5	+40 4·7	8 8	9·0	R^1	8	July 8
115	53·2384	17·5	+53 13·3	6·5	7·0	R^1	1	July 5
116*	39·4172	20·6	+39 46·5	7·5	8·0	OR^1	2	July 2
117*	15·4172	23·8	+15 52·8	8·3	8·5	R	1	July 9
118	39·4208	24·6	+39 35·7	9·2	var.	RR	17	July 9
119	45·3271	42·9	+45 37·6	8·8	8 6	RR	4	July 25
120	45·3289	44·9	+45 25·6	8·6	8·5	OR	3	July 25
121	50·3209	46·0	+50 20·9	7·3	7·5	R^1	1	July 5
122	49·3386	47·2	+49 41·5	6·8	7·5	R^1	2	July 5
123	45·3349	54·0	+45 47·8	8·1	8 0	RR	2	Dec. 15
124	47·3321	XXI. 6·5	+47 11·2	7·8	7·5	OR^2	4	July 25
125	49·3499	14·8	+49 34·9	7·0	6·5	OR^1	1	Oct. 27
126	62·1921	14·8	+62 26·3	8·7	9·0	OR	3	Nov. 5
127	48·3348	16·3	+48 51·7	8·2	8·5	R^2	1	Oct. 27
128	61·2134	22·8	+62 4·5	8·8	8·7	RR	5	Oct. 27
129	48·3470	37·7	+48 40·2	8 8	9·0	R	1	Oct. 27
130	70·1193	38·6	+70 15·7	7·0	8·5	OR^1	1	Dec. 2
131	57·2396	42·6	+57 32 0	7·5	8·7	ORR	1	Dec. 2
132	62·1997	49·6	+62 39 5	9·2	8·5	R^1	1	Nov. 5
133	65·1691	54·2	+65 36·2	6·5	6·5	OR^2	1	Nov. 5
134	38·4701	XXII. 6·3	+39 8·5	7·2	7 5	R^2	1	July 23
135	56·2793	26·0	+56 24·3	8·0	7·7	OR	4	Oct. 24
136	57·2562	30·2	+57 34·6	7·5	7·5	OR^2	8	Oct. 24
137	57·2568	32·4	+57 49·9	7·3	var.	OR^1	8	Oct. 24
138	42·4548	52·2	+42 23·5	6·8	7·0	OR^1	1	Nov. 30
139	57·2674	57·6	+57 37·3	8·4	8·5	R^1	1	Dec. 2
140	58·2534	57·8	+58 57·4	8·0	8·0	R^1	1	Dec. 2
141	48·4051	XXIII. 21·5	+48 52·9	9·3	9·0	OR	2	Nov. 16

Notes.

35. Closely f. H VII. 42, a little N. Mr. Webb, 1877, Dec. 14, observed a star 8·0 30′ S. a little f. I can find no red star in this place now. The reading of Mr. Webb's circle is given, leaving no doubt concerning the correctness of the assigned place.

39. Remarkable pair. Two equal stars, second decided green; 10·5 comes makes a triangle.

42. November 5, 8·0; November 17, 6·5. Webb's observation, 1876, January 1, orange ruby, 7·0. November 17, confirmed as to colour. 1878,

November 28, orange, but did not particularly attend to magnitude; but I do not think it could have been as large as 7·0.

43. Webb's observation, 1878, November 28, very pale ruby.

44. Blue star, 6·7, closely N.

47. Blue star, 20 sec. p., 8·0 magnitude.

48. Fine wide pair, 7·8 R, 8·0, o′.

49. Near Capella. October 9, 8·0; October 24, 6·0; November 5 and 14, 7·3; (46°·989 = 7·1, 46·985 = 7·7); November 28, 7·6; November 30 and December 14, 7·4.

51. Webb's observation, 1878, January 25, pale ruby, 8·5.

54. Blue star, 6·5, near.

58. Blue star, 9 0, near.

60. Webb's observation, 1874, March 26, 9·3, very pale ruby.

63. A remarkably red star f. + 0°·1600 by 6½ seconds.

64. Place only approximately found from B 147.

65. *h* 3945 Canis Majoris. 1884, February 10, 6·5, red; 7·0, remarkably blue; 1885, December 1, 7·0, orange; 8·0, blue, very fine. The large star is probably variable.

68. Webb's observation, 1877, September 5, 8·0, orange ruby.

83. Webb's observation, 1882, August 10, pale ruby, 9·0.

86. Webb's observation, 1872, May 31, pale orange-red.

93. Compared with 17°·3938 = 9·0. September 27, 9·5; October 27, 9·5. On December 7 I was much astonished at finding it fully 8·5.

96. A triangle. 25°·3883 is at the apex. The shades of colour in these two stars very perplexing. The latter once blue; at other times orange, and orange red. Its mean magnitude is 8·4.

98. Webb's observation, 1876, October 14. Very pale orange or ruby, 9·0; 1884, September 5, pale ruby, 9·0.

99. Fine field. Star p. 8·0, very blue.

100. Webb's observation, 1882, September 15, orange, with 10, pale blue, a few minutes p.

104. Webb's observation, 1879, September 3, 8·5, 9·5, 300° ± 50″, pale orange-red, pale yellow. On September 24, 25, I found the colours orange and blue, the blue being especially remarkable.

109. In a glorious field, the lucida 6½ orange. Webb's observation, 1880, August 9, beautiful wide group, with 6·0 pale orange. 1881, October 14, fine group attendant on 7·0, pale orange, with 9·0, pale orange, or orange red, S.

110. *h* 1470 comes 10·2, very blue. Webb's observation, 1879, September 25, 8·5, 9·5, pale orange-red; pale blue.

111. Comes 12·0, 25″ ±.

116. Webb's observation, 1876, August 30, 8½, orange ruby.

117. 8·0, blue, near. Webb's observation, 1873, September 12, ruby, 9·0. Comes 14 NP. 1875, October 2, pale ruby, 8 5. Two faint comites Np.

118. Compared with 39°·4210, 8·0, and 39°·4206, 8·8, clear blue. On the night of its discovery it was fully 7·9 out of focus, since which time it has irregularly diminished to 9·0. The colour is very fine. The Rev. T. W. Webb swept over this region repeatedly, but has no note of it.

124. A blue star near 7·3 magnitude.

133. A pale blue, 6·5, near.

137. Variable in some short period between 7·0 and 8·0. No. 136 used as a comparison star = 7·5. The following are all my observations of it:—

1885, Oct. 24	8·0	1885, Dec. 5	7·6
27	7·0	7	7·6
Nov. 16	7·2	11	7·2
Dec. 2	7·2	15	7·1

The New Star in Orion photometrically and spectroscopically observed at the Oxford University Observatory. By Prof. C. Pritchard, D.D., F.R.S.

Date of Observation. 1885.	Mag. of Nova when compared with *Polaris* =2·05.	Mag. of Nova when compared with 57 *Orionis* =6·03.	Adopted Mean Mag. of Nova.	Notes.
Dec. 23	6·49	6·43	6·46	
28	6·42	6·42	6·42	Fine night.
29	6·45	6·32	6·39	Very fine night.
1886. Jan. 2	6·47	6·39	6·43	Fine night; slight fog.
5	6·71	6·76	6·74	Fine night.
8	6·80	6·63	6·72	Fine night; but bad definition.
11	6·69	6·74	6·72	Fine night; haze low down.
18	6·92	6·83	6·87	Sky very fine.
26	6·77	6·90	6·82	Fine night.
Feb. 7	7·02	6·86	6·94	Bad definition; fine night.
23	6·93	7·13	7·03	Very fine night.
March 9	7·22	7·05	7·14	Fine nights; with low definition.
10	7·05	7·13	7·09	

Colour and Spectrum.—On December 23 the colour of the star was noted to be red-orange; spectrum columnar and four bands noticeable with Vogel eyepiece spectroscope. On December 29, in better definition, two other bands were seen in the red. On January 8 bright lines were specially looked for, but it was impossible to say whether any definite bright lines existed. The red colour has diminished considerably during the time the star has been watched, and is now not at all conspicuous.

I think that as far as the foregoing magnitude of the *Nova* are concerned, the accuracy is considerable; the main result being that from the time of its first observation here to the present, the star has decreased in brightness by about half a magnitude, viz. about 6·5 to 7·0 mag.

With regard to perhaps the more important question of the character of the spectrum, what is said above—viz. that it is seen here with six bands—must be read with the limitations due to the character of the small spectroscope employed; the larger and more delicate instrument belonging to the Observatory being at present at Greenwich. Still even with the largest forms of spectroscopes at the Royal Observatory and at Dun Echt the apparently contradictory results are perplexing.

Oxford University Observatory:
March 11, 1886.

Observations of the New Star in Andromeda, made at Mr. Wigglesworth's Observatory with the 15·5-inch Cooke Refractor. By J. Gerh. Lohse.

When the intelligence of the discovery of the new star in *Andromeda* was received, it was determined to connect the star micrometrically with some neighbouring stars, to compare its brightness with that of suitable stars, and to examine the spectrum as far as the instruments might allow.

The micrometric observations were made with a micrometer kindly lent by Lord Crawford. It was constructed by Merz, possesses only one micrometer screw, and has three movable wires and a set of fixed wires. A fine movement can be given to the whole micrometer by two screws in the adapter—an arrangement which has proved very convenient.

The observations of the old nucleus and of the 11th mag. star in the nebula are given singly; in the case of the other stars, however, the final result only is given. The corrections for refraction have been applied.

Measures of the Old Nucleus from the New Star.

1885.	Pos.	Dist.
Sept. 3	76°·50	16″·12
4	75·46	15·73
6	*	16·59
6	77·10	16·22
6	74·80	17·24
9	75·60	16·02
29	76·30	16·48
	75·96	16·343
	$\Delta\alpha = +1^s\cdot393$	$\Delta\delta = +3''\cdot96$

1885.	Pos.	Dist.
Nov. 30	*	15″·21
	76°·12	14·94
	76·24	14·95
	76·18	15·033
	$\Delta\alpha = +1^s\cdot283$	$\Delta\delta = +3''\cdot59$

* The first settings in Pos. on Sept. 6 and Nov. 30 were rejected at the telescope.

Measures of the 11th Mag. Star.

1885.	Pos.	Dist.
Oct. 1	262°·07	108″·27
	262·10	109·04
	—	109·80
	262·00	108·95
	—	108 28
	—	108·20
	262·06	108·76
	$\Delta\alpha = -9^{s}\cdot46$	$\Delta\delta = -15''\cdot00$

1885.	Pos.	Dist.
Nov. 30	261°·58	108″·67
	261·60	109·38
	261·59	109·03
	$\Delta\alpha = -9^{s}\cdot48$	$\Delta\delta = -15''\cdot95$

The following table contains the estimated magnitudes of the stars, measured from the new star, the position-angles and distances, the differences of R.A. and Declination, and the date on which the observations were made.

Mag.	Pos.	Dist.	$\Delta\alpha$	$\Delta\delta$	Date. 1885.
	° ′	″	s	″	
10	294 4·97	382·82	− 30·72	+ 156·21	Oct. 6
13	252 28·55	223·98	− 18·76	− 67·44	Oct. 1
10·2	345 11·78	439·53	− 9 88	+ 424·93	Oct. 1, 5, 26
11	341 31·08	292·32	− 8·14	+ 277·24	Oct. 1, Nov. 30
12·8	351 40·97	323·53	− 4·11	+ 320·12	Oct. 26
11·4	354 42·10	429·69	− 3·49	+ 427 86	Oct. 5
11·4	355 49·30	373·39	− 2·39	+ 372·39	Oct. 5
11·6	171 45·33	154·20	+ 1·94	− 152·62	Oct. 1, Dec. 1
11	156 46·20	230·28	+ 7·98	− 211·60	Oct. 1, Nov. 30
9·7			+ 55·52	+ 390·16	Oct. 29
11			+ 85·73	+ 248·98	Oct. 29
9			+ 123·24	+ 168 42	Sept. 4
10			+ 202·60	+ 397·49	Oct. 29

The other observations are given in chronological order :—

Sept. 3.—The spectrum is continuous, no lines could be distinguished in it with the Browning and McClean spectroscopes. The bright C line was very well seen in γ *Cassiopeiæ*.

The new star is one magnitude larger than the two 9th mag.

stars north of M 32, but fainter than the stars B.-W.$_{,}$ o^h·1057 and o^h ·1062–3.

Sept. 6.—The colour of the new star is yellow like that of several Bessel-Weisse stars in the neighbourhood, viz. B.-W.$_{,}$ o^h·896, o^h·953, o^h·965, o^h·1062. The star is of the same brightness as B.-W.$_{,}$ o^h·953, if anything a little brighter.

With a view to ascertain whether the appearance of the new star had produced a sensible alteration in the nebula, a small piece of paper was stuck to the field lens of a positive eyepiece, and the image of the new star placed behind it. The glare of the bright star being thus eliminated, the nebula, with the exception of the immediate neighbourhood of the new star, was very well seen, and appeared symmetrically arranged round the old nucleus, very much in the same way as I had known it before. Also without the use of a piece of paper on the eyepiece it was not difficult to see that the central part of the nebula is round and regularly arranged, with regard to the old nucleus as centre. The new star, therefore, as might have been expected, does not seem to have affected the form and distribution of matter in the nebula at all.

Sept. 9.—The new star in *Andromeda* is still as bright as B.-W.$_{,}$ o^h·953, but certainly not brighter. The colour is perhaps a little more reddish than formerly, but I am not quite certain about it. The spectrum is still continuous, but the part from F to about midway between F and G is fainter than in the spectra of neighbouring stars. In consequence of that, the spectrum near G appears comparatively brighter, but it does not seem to be brighter than the corresponding part of the spectrum of B.-W.$_{,}$ o^h·953, which has about the same brightness. The position of the fainter part in the spectrum depends on estimation only, there being no means for measuring the wave-length.

Sept. 12.—The new star is now decidedly fainter than B.-W.$_{,}$ o^h·953, and only one- or two-tenths of a magnitude brighter than the two stars north of M 32. The spectrum is continuous, and as long as that of D. M. + 40° 145, if not longer. Much attention was paid to the red end of the spectrum, and repeated comparisons of the two spectra convinced me that this part of the spectrum is quite as much developed in the new star as in D. M. + 40° 145. The observations were made with a McClean prism held in front of the eyepiece, and are only estimations.

Oct. 26.—The new star is of the same magnitude as the 10·2 mag. star in pos. 345°·21, and dist. 439″·53.

Nov. 28.—The new star is of the same brightness as the 11th mag. star preceding it in the nebula.

Dec. 1.—With a magnifying power of 196 the new star appears ·1 mag. brighter than the preceding star, but with a power of 127 it appears decidedly fainter, owing to the apparent increase of brightness of the nebulosity around it.

The determinations of the distance of the old nucleus from the new star seem to possess a special interest; for the observa-

tions made on November 30 give a smaller value for this distance than any of the observations made in September. This result is partly confirmed by the observations of the 11th mag. star in the nebula, sp. of the new star. The distance found on November 30 is a little larger than that obtained on October 1, as it ought to be if the distance between the nucleus and the 11th mag. star had remained unaltered; the difference, however, in this case is not so great.

The observations of Dr. Engelmann, published in *Ast. Nach.* No. 2683 and 2704, give similar results. The earlier series gives

Nova to old nucleus	16″·33
Nova to 11th mag. star	109·72

while the distances derived from later observations are

Nova to old nucleus	15″·96
Nova to 11th mag. star	109·98

The difference between the measures of the old nucleus is also in this case the larger one.

Although there are great discordances even between observations made on the same night, it seems difficult to explain the differences between the earlier and later observations entirely by errors of observation. The fact that two observers altered their mode of observing at the same time and in the same direction, while observing the same objects, seems very remarkable, unless there was some real change in the objects. If we assume that the new star has a large proper motion in the direction towards the nucleus, the greater part of the discordances vanishes. Unfortunately, no more observations can be obtained, the star having disappeared in the surrounding nebulosity.

Mr. Wigglesworth's Observatory, Scarborough:
1886, *March* 10.

Observations of Comets d, 1885 (Fabry), and e, 1885 (Barnard), made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of Declination.

Comet d, 1885.

Greenwich Mean Solar Time. 1886. d h m s	Observer.	✱ − ✱ R.A. m s	Corr. for Par. and Refract. in R.A. s	✱ − ✱ N.P.D. ′ ″	Corr. for Par. and Refract. in N.P.D. ″	No. of Comp.	Apparent R.A. h m s	Apparent N.P.D. ° ′ ″	Comp. Star.
March 7 7 28 52	H. T.	+3 21·30	+0·31	−5 25·2	−4·1	1	23 19 41·87	58 43 15·8	*a*
7 31 33		−0 30·70	+0·24	+7 27·0	−2·5	2	23 19 44·12	58 43 20·2	*b*
7 42 4		−1 14·45	+0·33	−9 31·3	−4·6	2	23 19 39·44	58 43 8·9	*c*

Comet e, 1885.

March 7 7 59 3	H. T.	−0 29·62	+0·22	+1 5·1	−3·3	5	1 54 42·04	67 10 33·8	*d*

Mean Places of Comparison Stars.

	Star's Name.	R.A. 1886·0. h m s	N.P.D. 1886·0. ° ′ ″	Authority.
(*a*)	64 *Pegasi*	23 16 21·07	58 48 42·6	9-year Catalogue.
(*b*)	W. B. (2) XXIII. 380	23 20 15·38	58 35 53·2	Weisse's Bessel (2).
(*c*)	Lalande 45897	23 20 54·36	58 52 42·2	Lalande.
(*d*)	Arg. Zone +22° No. 296	1 55 11·86	67 9 26·7	Rümker.

Notes.

(*d*) Comet bright, with nucleus.

(*e*) Not so bright as (*d*). Nucleus not well defined though suspected.

The observations are corrected for parallax and refraction. The initials H.T. are those of Mr. Turner.

Royal Observatory, Greenwich: 1886, *March* 12.

Observation of the Conjunction of Saturn and μ Geminorum, January 10, 1886. By John Tebbutt.

A set of differential measures of *Saturn* and the bright clock-star *μ Geminorum* was obtained here about three hours after the conjunction in Right Ascension on the 10th instant. The position filar micrometer, properly oriented, was employed on the $4\frac{1}{2}$-inch Equatorial, the transit of the planet's first limb and the star being observed across one of the close position-threads, and differences of Declination measured between the star and the planet's south or visible limb. The definition was generally fair, but the southern limb was shaded, and difficult to bring into accurate contact with the declination thread. The images, too, were occasionally rather unsteady. The following table exhibits all the measures obtained. The sidereal times of transit of the limb and the differences of the R.A. of the limb and star have been corrected by the addition of $0^s.75$, the time of the semi-diameter passing the meridian, and the differences of Declination by the addition of $9''.2$, the polar semi-diameter.

Windsor Sidereal Time.			Planet's Centre—Star. Diff. R.A.	Diff. Declin.
h	m	s	s	″
4	33	50·83	−2·40	+26·3
4	37	18·98	−2·25	+28·4
4	39	44·53	−2·40	+29·9
4	42	2·33	−2·50	+28·8
4	44	44·68	−2·60	+28·4
4	46	9·58	−2·15	+28·3
4	48	13·83	−2·65	+27·9
4	50	34·08	−2·70	+28·7
4	52	58·83	−2·75	+27·8
4	55	30·53	−2·75	+28·4
5	6	13·83	−2·90	+29·0
5	9	29·33	−2·75	+27·3
5	12	10·08	−2·85	+28·3
5	16	2·83	−3·00	+29·5
5	18	29·33	−3·00	+28·5
5	20	19·83	−2·95	+29·7
5	22	11·33	−3·15	+29·4
5	23	41·33	−3·25	+29·9
5	25	50·03	−3·05	+29·2
5	27	59·08	−3·25	+29·0
Means	5	1 40·56	−2·77	+28·6
Correction for Parallax			−0·02	−0·9
Adopted App. R.A. and Dec. of Star			$6^h\ 16^m\ 5·15$	+22° 34′ 5·2
Concluded Geoc. App. R.A. and Dec. of Planet			6 16 2·36	+22 34 32·9

The local mean time corresponding to this position is $9^h\ 42^m\ 0^s{\cdot}35$. The planet and star were observed differentially the same evening by means of the 3-inch Transit instrument, the resulting apparent R.A. of the planet's centre being $6^h\ 16^m\ 1^s{\cdot}18$. The evenings preceding and following the conjunction were cloudy. The star during the above observations appeared remarkably red.

Windsor, N.S. Wales:
1886, *January* 19.

On the Connection between Photographic Action, the Brightness of the Luminous Object and the Time of Exposure, as applied to Celestial Photography. By A. C. Ranyard.

The following experiments have been made with commercial dry plates by various makers. My object in the first instance was to obtain a comparison between the sensitiveness of the eye and the sensitiveness of the photographic film, for detecting small differences of illumination. With the eye a difference of one-sixtieth in the intensity of the illumination of two adjacent fields can be detected when the illumination is not too brilliant or too faint, and when the illuminated areas are of sufficient extent.

Fechner has shown that there is a physiological connection between the brightness of the illuminated fields and the difference of illumination which can be detected. He estimated that under the most favourable conditions a difference of one per cent. of illumination could be detected, and from the experiments of Helmholtz and others, there is no doubt that a difference of one-sixtieth can be recognised with certainty.

In order to make such a comparison, successive exposures of equal duration may be made on adjacent parts of the same plate, and the source of light removed through a measured distance between the exposures; or, if a connection can be established between the density of the photographic trace impressed upon the plate and the duration of the exposure, different parts of the plate may be exposed for different periods without moving the source of light, a course which greatly simplifies the experiment.

In order to test in a rough manner whether a light shining on a plate for a unit of time produced the same effect as a light of double the intensity shining for half the unit of time, one-half of a Wratten and Wainwright 'extra sensitive' plate was exposed to the light of a paraffine candle shielded from currents of air at a distance of five feet for a period of forty seconds, and the other half of the plate was exposed to the light of two similar candles for a period of twenty seconds. On developing the two halves of the plate appeared to be of about the same

darkness. This experiment was repeated with different modes of development, but whether the developing process was carried so far as to cause the tints to be very dense and opaque, or whether the development was manipulated so as to give faint tints, the two halves of the plate appeared of about the same density.

In order to carry this experiment further, an opaque screen was made, corresponding to the size of the photographic plates experimented with. A quarter of the screen was cut away, so that by placing the screen in front of the plate and turning it round, four successive exposures of areas touching one another could be made upon the same plate.

A Wratten and Wainwright 'extra sensitive' plate was exposed in this manner to the light of a candle, protected from currents of air, so that

the 1st quarter of the plate was exposed for 18 secs. to the candle at a dist. of 2 feet.
" 2nd " " " exposed for 40½ secs. to the candle at a dist. of 3 feet.
" 3rd " " " exposed for 72 secs. to the candle at a dist. of 4 feet.
" 4th " " " exposed for 112½ secs. to the candle at a dist. of 5 feet.

The exposures were made with as great accuracy as possible, the driving clock of my telescope, which can be made to tick at periods of 1½ sec., being used to measure the exposures. On developing the plate, it was found that all four quarters of the plate appeared about equally opaque. It will be noticed that the durations of the exposures are inversely as the square of the distance of the source of light. Several other plates were exposed with longer and shorter periods of exposure, varying inversely as the square of the distance of the candle. The plates were always developed by being entirely immersed in the developing solutions, so that all parts would presumably be equally acted upon. In every instance the four quarters of the plate are so nearly equal in density that it is difficult to decide with certainty which is the darkest.

In one of the longer exposures, where the four quarters of the plate were exposed for 25 minutes, 9 minutes, 4 minutes, and 1 minute, at distances of 15 feet, 9 feet, 6 feet, and 3 feet respectively, there is a slight difference of density, perhaps due to unequal burning of the candle, but the difference is so slight that a friend, to whom I showed this plate, selected the two upper quarters as being less dense than the two lower quarters, and when I removed the plate and turned it upside down, on presenting it to him a second time he again chose the two upper quarters as less dense than the two lower quarters.

These experiments seem to prove that for faint illumination,

such as that derived from a candle, the following law of photographic action is either true, or so approximately true, that for all ordinary purposes the deviations from the law, if any, may be neglected.

The photographic trace left upon a plate is directly proportional to the intensity of the light, and to the duration of the exposure.

Having satisfied myself with regard to this law, I proceeded to apply it to testing the sensitiveness of commercial dry plates by various makers to slight differences of illumination. The plates were placed in dark slides and exposed in steps by withdrawing the shutter at intervals of seven and a half seconds, so that a narrow band across the top of the plate was exposed for seven and a half seconds; a band of similar width immediately below it was exposed for fifteen seconds; the band below this was exposed for twenty-two and a half seconds, and so on to the bottom of the plate.

On some of the commoner plates when developed only six steps can be counted. The density of the photographic action increases gradually to the bottom of the plate, but the places where the shutter has stopped cannot be recognised by any sudden change in the density after the sixth step.

I was able to count the greatest number of steps on a Wratten and Wainwright 'extra sensitive' plate exposed to the light of a candle at a distance of 4 feet. On this eighteen steps could be counted with certainty, and possibly nineteen when the plate was examined against a background of clear sky. The following table gives the greatest number of steps which I was able to count on plates by various makers:—

Fry and Son's (Kingston) Dry Plate.

Exposed to the light of a candle at a distance of 4 feet: duration of exposures 7½ s., 15 s., 22½ s., 30 s., &c.
8 steps.

Rouch's (Extra Sensitive) Plate.

Exposed to the light of a candle at a distance of 4 feet: duration of exposures 7½ s., 15 s., 22½ s., 30 s., &c.
8 steps.

Ealing Plate (50 Extra Sensitive).

Exposed to the light of a candle at a distance of 4 feet: duration of exposures 6 s., 12 s., 18 s., 24 s., &c. 9 steps.

Derby Dry Plate Co. (Extra Rapid).

Exposed to the light of a candle at a distance of 5 feet: duration of exposures 9 s., 18 s., 27 s., 36 s., &c.
12 steps.

Wratten and Wainwright (Extra Sensitive).

Exposed to the light of a candle at a distance of 4 feet: duration of exposures 7½ s., 15 s., 22½ s., 30 s., &c.
18 (query 19) steps.

Thus the Wratten and Wainwright plate would not register a difference between the illumination given by 20 and 21 candles; and the difference of density of the photographic tint produced by the illumination of 19 and 20 candles was only recognised with difficulty and doubtfully. The photographic plate is therefore much less sensitive than the eye for detecting small differences of illumination. Prof. W. H. Pickering has been making some experiments with American dry plates, and finds that they will not show a difference of less than 5 per cent. of illumination. At first I thought that I could detect the position of the shutter up to some 30 steps, but on examining the plates more closely I found that there was a faint dark line across the plate wherever the shutter stopped. The dark line seemed to be due to reflection of light from the edge of the shutter; but when a little metal shade was made which threw a shadow on the edge of the shutter, as it was drawn up and down the dark line could not be detected, and the utmost number of steps counted was 19.

During a total solar eclipse the corona is not seen till about a minute or at most a minute and a half before totality commences, and observers seem to concur that it dies away in the increasing illumination as rapidly after totality; that is, all trace of the corona is lost when the thickest part of the Sun's crescent is less than a minute across. Taking into account the rapid decrease of light towards the Sun's limb, we shall be much within the truth in estimating that the corona is not seen till the illumination of the atmosphere about the Sun's place is less than one per cent. of the illumination of the atmosphere about the uneclipsed Sun. If the corona becomes visible when the illumination of the atmosphere is reduced to a brightness of thirty times the brightness of the corona, these observations would indicate that the brightness of the illuminated atmosphere round the uneclipsed Sun is at least 3,000 times as great as the brightness of the corona, and that unless the light of the corona is altogether of a different quality from that derived from the uneclipsed Sun, there is no chance of photographing the corona under ordinary daylight conditions. Unfortunately the spectroscopic photographs of the coronal light taken during eclipses, show that the monochromatic light of the corona (though it seems to differ in amount from eclipse to eclipse) never bears any large proportion to the continuous spectrum of the corona, or solar spectrum dispersed by the corona, as it should more properly be called. For the dark lines in the background of continuous spectrum, which recent observers believe that they have identified with certainty with the dark lines of the ordinary solar spectrum, lead to the sup-

position that the continuous spectrum of the corona is mainly due to dispersed solar light. If the light is dispersed by particles which are large compared with the wave-length of light, the relative intensity of different parts of the spectrum will not be affected by the dispersion, and there is no chance of photographing the corona under ordinary daylight conditions except by isolating and photographing the monochromatic images which bear so small a proportion to the general light of the corona. There is some evidence, though I do not look upon it as conclusive for all photographic processes, that the position of the maximum of photographic activity in the coronal spectrum does not differ materially from the position of the maximum of photographic activity in the ordinary solar spectrum. The position of the continuous spectrum of the corona relatively to the position of the bright coronal and prominence lines which have been identified in the eclipse photographs shows that the distribution of photographic action in the coronal spectrum does not differ very materially from the distribution of the photographic action in the ordinary solar spectrum.

The Great Shower of Andromedes, 1885. By T. W. Backhouse.

The early part of the shower on November 27, 1885, was well seen at Sunderland. The following table gives the number of meteors actually counted by myself at different times during the display. Column (1) contains the times at which the meteors were counted; (2), the duration in seconds of each counting; (3), the estimated proportion of clear sky in the direction of observation; (4), the number of seconds in column (2) diminished for the extent of cloud; in (5) mention is made of hindrances to visibility of meteors in the portion of sky not clouded; then (6), the number of meteors counted in each interval; (7), the number per minute corrected for the amount of cloud; lastly, in (8), the approximate average direction of the point of sight is designated.

Table I.

Time.	Duration of watch.	Sky.	Corrected duration of watch.	Hindrances.	Meteors.	Rate per minute.	Point of sight.
h m s m s	s		s				
4 25 to 35	420	1·0	420	Very bright twilight	2	0·3	
5 5 to 6	60	1·0	60	Bright twilight and gaslight	5	5	
5 7 50 to 9 5	75	1·0	75	Twilight	22	17·6	Near radiant
5 10 50 to 11 50	60	1·0	60		9	9	
5 12 50 to 14 32	102	1·0	102		25	14·7	ε Cygni
5 25 50 to 27 12	82	1·0	82	Slight twilight	26	19	Radiant point
5 40 40 to 41 27	47	0·95	44·6		21	28·3	
5 42 15 to 43 30	75	0·9	67·5		63	56	Average altitude 40°, in south
6 2 0 to 2 53	53	1·0	53		57	64 5	Zenith, facing south
6 10 40 to 11 30	50	1·0	50		54	64·8	α Andromedæ
6 12 15 to 14 45	150	1·0	150		160	64	Polaris
6 41 5 to 42 5	60	0·6	36		33	55	
7 4 12 to 5 0	48	0·5	24	Thin cloud	8	20	
7 5 25 to 7 3	78	0·7	68·6		30	26·1	

I also watched for four minutes—part of the time near the radiant point, and part below λ *Tauri*—with a 4¼-inch Refractor (power 20) between $6^h\ 49^m$ and 56^m, when the sky was nearly clear, but saw no meteors.

Table II. compares this shower with those of 1866 and 1872.

TABLE II.

	Time of maximum observed.	Actual number seen per minute.	Amount of cloud.	No. per minute corrected for cloud.
	h m			
1866, Nov. 13	13 9	61	0	61
1872 „ 27	6 21 to 27m	14	0·5	28
1885 „ 27	6 11	65	0	65

This probably gives a pretty fair comparison, though from other accounts of the shower of 1872 I think I did not see its maximum, as it was mostly overcast here from $6^h\,40^m$ to $9^h\,0^m$; also as my eyes have been growing more sensitive, that might make a slight increase in the number of meteors seen in the late shower, compared with the previous ones.

About $6^h\,17^m$ I recorded the magnitudes of the meteors as well as their rapid appearance would permit. The number and percentage seen of each magnitude out of a total of 35 noted is shown in

TABLE III.

	= Ψ	1st mag.	2nd	3rd	4th	5th	6th mag.
Number	1	4	3	7	12	8	0
Percentage	3	11	9	20	34	23	0

This was the only attempt I made to ascertain the magnitudes. I had the impression that the proportion of bright meteors was, in general, greater than at the time I observed the magnitudes. In any case it was very much greater than in 1872, certainly so previous to 7^h on that occasion. This time those as bright as *Jupiter* were very numerous, and many equalled *Venus*. Several were bright enough to cast a glow for some distance around; and one, I believe, illumined the whole sky—I did not see this one, but only its light.

All the bright meteors had bright trains, deep red in colour, but in some cases partly of other colours—chiefly whitish. The faint meteors had no perceptible trains as a rule; but those of about 3rd mag. had trains, yet too faint to show any colour. The 2nd mag. ones often showed the red. I saw but one persistent train; this was in the case of a meteor at $6^h\,4^m$, which equalled *Venus* at her brightest, a portion of the train being still faintly visible to the naked eye at $6^h\,10^m$, between γ and 11 *Camelopardi*. I noted its position very exactly for comparison with any other observation of it elsewhere; but though Mr. John Stevenson reports one such seen from near Edinburgh about 6^h, this, being near β *Aquilæ*, must have been another.

Between $6^h\,19^m$ and 28^m I took notice of the length of path and the duration of those far from the radiant point. As a rule, the brighter the meteor the longer the path and duration. The average of three 1st mag. ones gave a course of 13°, duration

$1^s{\cdot}9$; of three 2nd mag. ones, 10° and $1^s{\cdot}5$. The fainter ones, say 3rd mag. and less, varied from $0^s{\cdot}4$ to $1^s{\cdot}1$ in duration; average probably $0^s{\cdot}7$.

I have not calculated the position of the radiant yet, but can confirm the observations of others that it was an area of several degrees in diameter. It is a striking circumstance that observers in widely distant places locate it differently, Mr. John Ballot, at Rolfontein in the Transvaal, putting it near ϵ *Trianguli* in the direction of 7. This point, as seen from the Transvaal, would be above (though not exactly above) the position of the average point of radiation derived from the observations in Europe; which fact (if the position is a correct one) suggests that the paths of the meteors may be deflected downwards by the Earth's attraction. On the other hand, Mr. H. J. Bell, observing in the Mauritius, places the radiant a few degrees north of γ *Andromedæ*. There is another reason which would partly account for the variously assigned position of the radiant point, but only partly—i.e. that a larger proportion of those meteors proceeding from the side of the radiant area nearest the zenith must be visible from any place than of those proceeding from the lower side of the area, owing to the correction required for obtaining the zenith horary number being less for the former. The motion of the radiant point observed by Denza and Schiaparelli would likewise be partly accounted for by the deflection of the paths.

I saw but two unconformable meteors, the former of them being the earliest I observed, viz. at $4^h\ 31^m$, when *Venus* was the only star visible at the time, so far as I noticed. It was far brighter than *Venus* at her brightest. I noted its position with respect to trees, &c., and afterwards ascertained that it appeared about R.A. $29\frac{1}{2}°$, D. $+22°$, and was directed towards about ϕ *Pegasi*. Its course was about 8° after I first saw it, and was very slow; duration probably 3^s or 4^s. It had a train of large and very bright sparks—I believe green.

The next meteor I saw occurred one or two minutes later, and was undoubtedly an *Andromede*. It was about equal to *Jupiter* in brilliancy, and appeared about R.A. 43°, D. $+18°$. Both this and the previous one I at first took to be fireworks, so observed them less carefully than I otherwise should have done; but the positions cannot be far wrong, especially of the first. The fact that they were meteors is proved by their having been seen from places many miles apart.

These, however, were not the earliest meteors seen here, for at $3^h\ 30^m$, or perhaps a little earlier, one was seen in the west. It must have been exceedingly brilliant to attract attention at all, the observer being very short-sighted. The same meteor, probably, was seen at Scarborough, where it appeared in the north-west. One was also seen from near Darlington about the same time, but, as far as I can gather from the description, was in the north-east, and must therefore have been another. These seem to have been *Andromedes*.

The sky gradually clouded over here between 7^h and $7^h\ 15^m$, and continued overcast, or nearly so, the rest of the night, so far as I observed; but the following nights were clear, affording an opportunity of observing the gradual decline of the *Andromede* shower. The next table exhibits the duration of my watch on these nights, with the number of *Andromedes* as well as of all meteors I observed:—

TABLE IV.

Day.	Time.	Duration of watch.	Corrected duration of watch.	Hindrances.	Number of Andromedes seen.	Number of all Meteors seen.	Hourly rate of Andromedes.
1885.	h m h m	m	m				
Nov. 28	5 55 to 6 15	11	5	Thin cloud and gaslight	1	1	12
	8 5 to 11 23	79	78		17	22	13·1
	11 25 to 12 15	33	33	Moonlight, at first very slight	4	4	7·3
	Total	123	116		22	27	11·4
Nov. 29	5 41 to 11 30	52½	36	Aurora and thin cloud	5	6	8·3
	11 39 to 12 19	28½	23		3	7	7·8
	Total	81	59		8	13	8·1
Nov. 30	5 31 to 11 48	84	84		4	11	2·8
Dec. 1	5 50 to 11 43	61	61		0	3	0

After this the only decided *Andromede* I saw was a meteor on December 6; but one, which very likely belonged to the shower, appeared on the 4th.

Sunderland:
1886, *February* 8.

Occultations of Stars by the Moon, and Phenomena of Jupiter's Satellites, observed at Stonyhurst Observatory. By Rev. S. J. Perry, F.R.S.

1885.	Phenomena.	Limb.	G.M.T. h m s	Remarks.
Mar. 22	Disapp. 111 *Tauri*	Dark	6 44 53·8	Sky very good.
	Reapp. ,,	Bright	7 50 34·4	,, ,, ,,
22	Disapp. 117 *Tauri*	Dark	8 51 26·8	,, ,, ,,
	Reapp. ,,	Bright	9 23 18·1	,, ,, ,,
27	Disapp. B.A.C. 3529	Dark	10 17 13·3	Passing clouds.
	Reapp. ,,	Bright	11 17 31·9	Sky pretty good.
27	Disapp. 43 *Leonis*	Dark	11 31 55·5	Sky good.
	Reapp. ,,	Bright	12 21 13·8	
Sept. 25	Disapp. μ *Piscium*	Bright	8 15 47·6	Good.
	Reapp. ,,	Dark	9 11 46·8	
Nov. 17	Disapp. B.A.C. 8365	Dark	10 40 28·5	Very good.
	Reapp. ,,	Bright	11 37 56·8	Haze: observation poor.

The observations are always given in G.M.T. and not in L.M.T., the longitude, $9^m\ 52^s{\cdot}68$ W., having been determined in 1850 by two complete trips from Liverpool to Stonyhurst and back with three excellent chronometers. The results are published in the eleventh volume of the *Monthly Notices* in a paper by the Rev. A. Weld. The above observations were all taken by the same observer, Mr. W. Carlisle, and a dark screen was always used.

Phenomena of Jupiter's Satellites.

	Sat.	Phenomena.	G.M.T. h m s	Corr. of *N.A.* m s	Observer.	Remarks.
1885, Feb. 2	4	Ec. Disap. Fading	10 3 2		S. J. P.	Definition good.
		½ light	4 49		,,	
		= 11th Mag. *	6 55·5		,,	
		Last seen	9 7	+ 39	,,	If anything, a little too early.
3	1	Ec. Disap. Fading	8 59 49		W. C.	Passing clouds at commencement of observation.
		½ light	9 0 54		,,	
		Last seen	2 2	+ 8	,,	
19	1	Oc. Disap. External contact	7 14 34		,,	Definition very poor. Unsteady.
		Bisection	15 28		,,	
		Last seen	16 41		,,	
19	4	Ec. Reap. First seen	8 44 57	+ 3 3	S. J. P.	Late, from nearness to limb. Definition good, but changing.
		½ light	50 52		,,	
19	1	Oc. Reap. First seen	9 33 5		W. C.	Definition good.
		Bisection	34 44		,,	
		Last contact	36 53		,,	
28	2	Oc. Disap. External contact	8 45 25		,,	Definition good, and planet very steady.
		Bisection	47 26		,,	
		Last seen	49 7		,,	
March 6	3	Tr. Egress Internal contact	7 12 9		,,	Unsteady.
		Bisection	14 33		,,	
		Last contact	17 12		,,	

	Sat.	Phenomena.	G.M.T. h m s	Corr. of *N.A.* m s	Observer.	Remarks.
1885, Mar. 6	1	Tr. Egress External contact	7 58 50		W.C.	Definition good.
		Bisection	8 0 30		,,	
		Internal contact	2 25		,,	
6	3	Sh. Egress Internal contact	8 41 5		,,	Definition good.
		Bisection	43 18		,,	
		Last seen	45 33		,,	
6	1	Tr. Egress Internal contact	10 17 5		,,	Fairly good sky.
		Bisection	18 41		,,	
		External contact	20 16		,,	
6	1	Sh. Ingress Internal contact	10 38 59		,,	Sh. exceedingly small, but dark.
		Bisection	40 0		,,	
		Last seen	41 3		,,	
13	1	Tr. Ingress External contact	9 45 44		,,	Definition good.
		Bisection	47 32		,,	
		Internal contact	49 20		,,	
13	3	Tr. Egress Internal contact	10 30 48		,,	Good.
		Bisection	34 5		,,	
		Last contact	37 18		,,	
13	1	Tr. Egress Internal contact	12 2 4		,,	Definition good; limb boiling.
		Bisection	3 35		,,	
		Last contact	5 2		,,	

	Sat.	Phenomena.	G.M.T. h m s	Corr. of *N.A.* m s	Observer.	Remarks.
1885, Mar. 14	1	Oc. Disap. First contact	6 51 34		W.C.	
		Bisection	53 23		,,	Sky very hazy.
		Last seen	55 8		,,	
14	1	Ec. Reap. First seen	9 43 30	+ 10	,,	
		½ light	44 33		,,	Sky very hazy.
		Full light	45 36		,,	
14	2	Oc. Disap. First contact	13 18 9		,,	
		Bisection	19 58		,,	Difficult; sky bad.
		Last seen	21 23		,,	
22	1	Tr. Egress Internal contact	8 14 3		,,	
		Bisection	15 56		,,	Tremulous. Definition fairly good.
		Last contact	17 47		,,	
April 17	2	Tr. Egress External contact	9 6 59		J. R.	Fair observation.
18	4	Tr. Egress Internal contact	11 31 38		W. C.	
		Bisection	34 35		,,	Sky very hazy.
		External contact	11 37 38		,,	
27	4	Ec. Reap. First seen	8 36 4	+ 21	,,	
		½ light	39 58		,,	Good.
		Full light	43 41		,,	
Nov. 15	3	Ec. Reap. First seen	17 52 19	+ 1 14	,,	
		½ light	54 14		,,	Very good.
		Full light	59 1		,,	

Occultations observed at Beloit, Wisconsin, in 1884–85.

By J. Tatlock.

(*Communicated by the Secretaries.*)

From August 1884 to July 1885 I was in charge of a small Observatory at Beloit, Wisconsin, and during that time the observation of occultations of stars by the Moon was made a prominent feature of the Observatory work. Such observations of this nature as I succeeded in making are given in what follows. The list is comparatively small, but much of my time was occupied with other matters and duties, and the weather during the winter of 1884–85 and the spring of 1885 was particularly unfavourable for astronomical work in this locality.

The position of the Observatory is assumed to be—

Long. $5^h\ 56^m\ 7^s{\cdot}30$ West of Greenwich,
Lat. $+42°\ 30'\ 9''$.

These coordinates were determined by triangulation from points in the immediate vicinity of the Observatory which had been fixed by the State Survey of Wisconsin, whose positions depend upon the Coast Survey (telegraphic) longitude and latitude of Madison. This position is undoubtedly susceptible of correction, but I think it is abundantly accurate for the reduction of the observations contained in this paper.

The occultations were observed with an Equatorial having a Clark objective of 9·5 English inches in diameter. A power of 220 was usually employed, though some of the observations were made with a power of 100. A part of the occultations were observed by the eye-and-ear method, using a sidereal chronometer, but the majority were registered on the chronograph, with a Howard mean-time clock graduating the sheet.

I made a great effort to have the time determination as accurate as possible. The Transit was an instrument of antique construction, with an objective of 2·5 inches in diameter, and fitted with a diagonal eyepiece with a power of about 35. The instrument was rather unsteady in level and azimuth, and I consequently determined the inclination of the axis at frequent intervals, at least once for every star. The collimation was determined from the star observation, and as this demanded a reversal of the instrument, I always assumed, in the reduction, two values of the azimuth constant. The time determinations were made by the eye-and-ear method, using a sidereal chronometer, and the time was found on every night on which occulta-

tions were observed. I find that the probable error of a clock correction from a single star is $\pm 0^s.095$; and as four time stars were always observed, if possible, the probable error of an adopted clock correction is about $\pm 0^s.05$. Considering the character of the instrument, this is as good a result as could be expected. The rates of the chronometer and clock were checked by frequent comparison.

I have given in the accompanying table both the Beloit and the Greenwich time of the observations, the longitudes mentioned above having been used in the conversion. The last column of the table denotes the method according to which the observation was made, E denoting the eye-and-ear, and C the chronographic. There is a little uncertainty concerning the identity of a few of the small stars, as the facilities for identification at my disposal were extremely limited.

I have also given the places of the Moon, both geocentric and apparent, computed for the Greenwich times of the occultations. The geocentric places were taken from the *American Ephemeris and Nautical Almanac*, and the apparent places were computed by the formulæ given in Chauvenet's Astronomy.

I have not given the places of the stars, because I have not the necessary catalogues at hand.

No.	Date.	Star.	Phase.	Limb.	Beloit M. T.	Greenwich M. T.	
	1884.				h m s	h m s	
1	Aug. 31	ρ' Sagittarii	Immersion	Dark	10 44 7·9	16 40 15·2	E
2	Sept. 10	D. M. + 16° 591	,,	Bright	12 45 48·3	18 41 55·6	E
3	10	D. M. + 16° 602	,,	,,	13 45 13·0	19 41 20·3	E
4	11	115 Tauri	,,	,,	13 55 42·4	15 3 0·2	E
5	11	115 Tauri	Emersion	Dark	19 51 49·7	29 59 7·5	E
6	Sept. 24	χ Ophiuchi	Immersion	,,	7 39 57·9	13 36 5·2	E
7	Oct. 10	λ Geminorum	,,	Bright	17 14 46·0	23 10 53·3	E
8	Nov. 8	A^2 Cancri	,,	,,	12 34 39·4	18 30 46·7	E
9	8	D. M. + 13° 1995	,,	,,	12 36 58·4	18 33 5·7	E
10	8	A^2 Cancri	Emersion	Dark	13 40 8·2	19 36 15·5	E
11	Nov. 8	α Cancri	Immersion	Bright	18 21 38·7	24 17 46·0	E
	1885.						
12	Jan. 25	63 Tauri	,,	Dark	13 14 22·2	14 4 56·5	C
13	25	63 Tauri	Emersion	Bright	19 10 29·5	20 1 3·8	C
14	Jan. 28	λ Geminorum	Immersion	Dark	6 43 6·1	12 39 13·4	C
15	Feb. 20	LL. 5725	,,	,,	11 15 4·4	17 11 11·7	C
16	22	B. A. C. 1526	,,	,,	9 2 0·2	14 58 7·5	C
17	Feb. 22	B. A. C. 1526	Emersion	Bright	9 49 32·9	15 45 40·2	C
18	Mar. 19	38 Arietis	,,	,,	8 21 35·4	14 17 42·7	C
19	19	D. M. + 11° 385	Immersion	Dark	8 23 33·3	14 19 40·6	C

No.	Date.	Star.	Phase.	Limb.	Beloit M. T.			Greenwich M. T.			
	1885.				h	m	s	h	m	s	
20	Mar. 19	D. M. + 11° 387	Immersion	Dark	8	32	27·6	14	28	34·9	C
21	19	D. M. + 11° 386	„	„	8	33	55·5	14	30	2·8	C
22	21	D. M. + 16° 641	„	„	8	41	15·2	14	37	22·5	E
23	22	D. M. + 17° 979	„	„	8	16	14·1	14	12	21·4	C
24	22	Anon.	„	„	8	37	40·9	14	33	48·2	E
25	22	130 Tauri	„	„	10	59	29·9	16	55	37·2	C
26	22	D. M. + 17° 1006	„	„	11	5	39·2	17	1	46·5	C
27	22	D. M. + 17° 1011	„	„	11	16	39·8	17	12	47·1	C
28	22	130 Tauri	Emersion	Bright	11	48	18·5	17	44	25·8	C
29	23	D. M. + 17° 1336	Immersion	Dark	7	12	24·4	13	8	31·7	C
30	23	D. M. + 17° 1341	„	„	7	14	57·4	13	11	4·7	C
31	23	D. M. + 17° 1344	„	„	7	20	14·8	13	16	22·1	C
32	23	Anon.	„	„	7	21	56·0	13	18	3·3	C
33	Mar. 24	D. M. + 16° 1546	„	„	9	26	28·2	15	22	35·5	C
34	Apr. 20	D. M. + 16° 1493	„	„	10	1	38·4	15	57	45·7	C
35	May 21	*d* Leonis	„	„	10	57	6·7	16	53	14·0	C
36	June 16	D. M. + 9° 2338	„	„	8	50	44·2	14	46	51·5	C
37	16	D. M. + 9° 2341	„	„	9	27	6·9	15	23	14·2	C
38	16	Anon.	„	„	9	29	36·9	15	25	44·2	C
39	June 18	D. M. + 1° 2585	„	„	9	16	25·1	15	12	32·4	C

No.	Date.	α	δ	π	S	Δα	α′	Δδ	δ	S
	1884.	h m s	° ′ ″	′ ″	″	′ ″	h m s	′ ″	° ′ ″	″
1	Aug. 31	289 0 22·22	−17 4 48·79	55 6·40	900·20	−23 17·21	288 37 5·01	−45 42·97	−17 50 31·76	905·85
2	Sept. 10	63 36 32·44	+17 7 5·10	59 21·13	969·62	+40 32·44	64 17 4·88	−32 19·43	+16 34 45·67	978·55
3	10	64 13 5·84	+17 11 14·84	59 21·03	969·59	+33 56·33	64 47 2·17	−29 41·98	+16 41 32·86	980·99
4	11	79 10 47·49	+18 17 37·19	59 15·08	968·02	+39 34·42	79 50 21·91	−31 0·83	+17 46 36·36	977·65
5	11	79 52 34·07	+18 19 0·76	59 14·72	967·92	+31 21·16	80 23 55·23	−28 2·12	+17 50 58·64	980·17
6	Sept. 24	245 30 28·53	−17 17 13·51	54 13·55	885·88	−34 2·09	244 56 26·44	−41 55·38	−17 59 8·89	888·82
7	Oct. 10	107 28 24·94	+17 9 28·31	58 56·56	962·99	+ 6 41·52	107 35 6·46	−25 32·65	+16 43 55·66	977·99
8	Nov. 8	129 35 58·19	+13 35 38·38	58 38·22	958·00	+42 33·18	130 18 31·37	−35 27·80	+13 0 10·58	964·11
9	8	129 37 18·70	+13 35 20·92	58 38·12	957·97	+42 25·21	130 19 43·91	−35 22·39	+12 59 58·53	964·21
10	8	130 13 51·48	+13 27 23·00	58 36·07	957·42	+37 17·23	130 51 8·71	−33 4·56	+12 54 18·44	966·46
11	Nov. 8	132 55 43·54	+12 50 57·11	58 26·92	954·94	− 8 58·85	132 46 44·69	−29 19·54	+12 21 37·57	968·48
	1885.									
12	Jan. 25	64 42 53·46	+16 59 12·28	59 51·14	977·78	−45 33·57	63 57 19·89	−36 25·85	+16 22 46·43	983·20
13	25	65 14 30·44	+17 2 59·22	59 52·30	978·09	−46 11·95	64 28 18·49	−39 4·42	+16 23 54·80	980·05
14	Jan. 28	107 1 11·50	+17 29 33·45	60 46·78	993·00	+40 6·65	107 41 18·15	−32 10·06	+16 57 23·39	1003·13
15	Feb. 20	45 33 14·64	+13 34 11·14	58 28·58	955·30	−44 13·87	44 49 0·77	−39 7·36	+12 55 3·78	956·82
16	22	72 56 36·98	+17 37 48·51	59 16·10	968·23	−27 6·29	72 29 30·69	−27 36·06	+17 10 12·45	981·30
17	Feb. 22	73 25 57·60	+17 40 8·29	59 16·78	968·42	−33 59·32	72 51 58·28	−29 19·21	+17 10 49·08	979·87
18	Mar. 19	40 36 0·09	+12 23 35·67	58 40·64	958·60	−44 3·42	39 51 56·67	−37 31·45	+11 46 4·22	962·37
19	19	40 37 8·28	+12 23 51·56	58 40·68	958·61	−44 5·98	39 53 2·30	−37 35·79	+11 46 15·77	962·28
20	19	40 42 17·46	+12 25 3·55	58 40·81	958·65	−44 21·35	39 57 56·11	−37 55·60	+11 47 7·95	961·88
21	19	40 43 8·37	+12 25 15·34	58 40·83	958·65	−44 16·38	39 58 51·99	−37 58·74	+11 47 17·60	961·81

No.	Date. 1884.	α	δ	π	S	Δα	α′	Δδ	δ′	S
22	Mar. 21	69 26′ 43″·14	+17° 14′ 24″·53	59 8″·04	966″·05	−50′ 28″·98	68 36′ 14″·16	−31′ 59″·51	+16° 42′ 25″·02	975″·07
23	22	83 59 43·78	+18 7 57·56	59 13·83	967·70	−30 22·53	83 29 21·25	−27 55·39	+17 40 2·17	980·14
24	22	84 13 1·72	+18 8 16·21	59 13·89	967·72	−33 23·29	83 39 38·43	−28 45·45	+17 39 30·76	979·41
25	22	85 40 59·92	+18 9 56·55	59 14·24	967·82	−45 26·26	84 55 33·66	−35 45·56	+17 34 10·99	973·24
26	22	85 44 48·98	+18 9 59·89	59 14·25	967·82	−45 36·96	84 59 12·02	−36 5·88	+17 33 54·01	972·06
27	22	85 51 38·85	+18 10 5·87	59 14·26	967·81	−45 51·23	85 5 47·62	−36 42·37	+17 33 23·50	972·38
28	22	86 11 17·02	+18 10 21·65	59 14·36	967·83	−45 59·30	85 25 17·72	−38 27·73	+17 31 53·92	970·17
29	23	98 13 26·60	+17 56 58·66	59 15·18	968·00	− 9 20·07	98 4 6·53	−25 3·67	+17 31 54·99	983·16
30	23	98 15 1·32	+17 56 53·96	59 15·17	968·00	− 9 49·32	98 5 12·00	−25 5·05	+17 31 48·91	982·13
31	23	98 18 17·85	+17 56 44·15	59 15·17	968·00	−10 49·76	98 7 28·09	−25 10·07	+17 31 34·08	983·06
32	23	98 19 20·54	+17 56 41·02	59 15·17	968·00	−11 8·97	98 8 11·57	−25 11·50	+17 31 29·52	983·04
33	Mar. 24	114 20 41·54	+16 29 15·46	59 11·52	966·99	−23 4·37	113 57 37·17	−27 48·20	+16 1 29·26	980·49
34	Apr. 20	111 25 43·80	+16 54 38·60	59 20·97	969·65	−42 47·06	110 42 56·74	−33 48·16	+16 20 50·44	976·65
35	May 21	164 2 9·32	+ 4 56 34·62	59 49·07	944·59	−37 25·37	163 24 43·95	−37 10·02	+ 4 19 24·60	951·23
36	June 16	145 45 17·32	+10 34 58·70	59 37·18	974·00	−42 52·45	145 2 24·87	−37 12·99	+ 9 57 45·71	979·68
37	16	146 6 36·86	+10 29 16·87	59 35·99	973·68	−44 18·83	145 22 18·03	−38 22·01	+ 9 50 54·86	977·49
38	16	146 8 4·72	+10 28 53·33	59 35·91	973·66	−44 22·51	145 23 42·21	−38 26·20	+ 9 50 27·13	977·34
39	18	172 48 35·31	+ 2 21 1·63	57 54·65	946·06	−34 47·45	172 13 47·86	−38 9·29	+ 1 42 52·34	953·39

Hoosac Falls, N.Y., U.S.A.: 1885, *January* 14.

Erratum in Annual Report, 1886.

Page 207, line 19 from bottom, *for* deviation *read* direction.

*** The Council are indebted to the Editor of *Nature* for permission to insert the obituary notice of Sir F. J. O. Evans, published in the Annual Report.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVI. APRIL 9, 1886. No. 6

J. W. L. GLAISHER, M.A., F.R.S., President, in the Chair.

W. H. S. Monck, M.A., 13, Belvedere Place, Dublin, was balloted for and duly elected a Fellow of the Society.

On some suggested Improvements in the Practical Working of M. Loewy's New Method of Determining the Elements of Astronomical Refraction. By David Gill, LL.D., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope.

The progressive requirements of exact astronomy have, for a long time, demanded in vain a direct, simple, and practical method for determining the elements of refraction.

The method proposed (*Comptes Rendus*, tome cii. p. 74) appears at last to indicate the means by which such a determination can be made with all desirable accuracy, and the author, M. Loewy, deserves the congratulations, as well as the thanks, of astronomers for the powerful, elegant, and simple method which he has suggested.

M. Loewy proposes to place a prism having two silvered reflecting surfaces inclined to each other at 45° in front of the object-glass of a telescope. The prism is mounted symmetrically with respect to the optical axis of the telescope; the line of the intersecting reflecting planes being next the object-glass, and capable of rotation in a plane at right-angles to the axis of the telescope.

The arrangement is shown in the accompanying fig. 1 :—

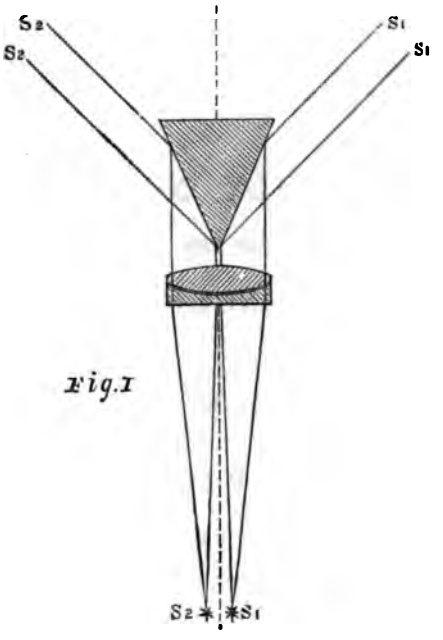

Fig. 1

The figure represents the path of the rays from stars S_1 and S_2, where the angle between the stars is slightly greater than twice the angle of intersection of the reflecting planes of the prism.

The apparatus is mounted as an ordinary equatorial telescope. In this way any two stars in the heavens which are 90° on the great circle apart ± (the diameter of the field of view) can be seen simultaneously in the field when the axis of the telescope is directed to the middle point between the stars, and the prism is turned so that the line of intersection of its reflecting planes is at right-angles to the great circle joining the stars. The distance between the images of the stars in the field of view will vary in consequence of the changes of refraction due to the change of altitude produced by the diurnal motion. The apparent angle between the stars themselves will be a maximum when both stars have the same altitude, and a minimum when one is on the horizon and the other at the zenith.*

If a spider-line micrometer is attached to the eye-end of the telescope so that its direction of measurement is at right-angles

* The angle between the images in the field of view will follow the same law when the angle between the stars is greater than twice the angle of the prism, but will be reversed when the angle between the stars is less than twice the angle of the prism.

to the line of intersection of the reflecting planes of the prism, then this micrometer will measure the true change of the distance between the stars (that is, the variation of the effect of refraction) entirely independent of any small changes in the position of the prism with respect to the axis of the telescope, such as may be supposed to be produced by flexure of the support of the prism.

It will be seen from this brief summary of M. Loewy's proposal that the investigation of the elements of refraction may thus be made to depend entirely on easy differential measures, which can be rapidly made with practical freedom from all systematic errors except those which may be due to atmospheric chromatic dispersion.

Having considered the practical details which are necessary for the most perfect realisation of these ideas, I am led to propose a few modifications of M. Loewy's apparatus, which promise to increase the ease of working as well as the general accuracy and utility of the method.

1. Instead of a fixed telescope-tube with rotation of the prism in front of the object-glass, let the prism be attached rigidly to the cell or mounting of the object-glass, the latter attach rigidly to the tube, set the webs of the spider-line micrometer permanently parallel to the line of intersection of the reflecting surfaces of the prism, and give rotation to the whole tube round its own axis, by placing it in a cradle attached to the Declination axis, after the manner of the tube of a modern heliometer. A position-circle attached to the tube, and read by verniers attached to the cradle, should also be provided. By these means a sufficiently rigid relation between the prism and spider-line micrometer would be preserved, and the necessity for computing the setting of the direction of measurement for the spider-line micrometer would be entirely avoided.

To find the two stars it would only be necessary to direct the tube, by the R.A. and Declination Circles, to the hour-angle and Declination of the middle point between the stars, and to set the position-circle to the angle which the great circle joining the two stars makes with a circle of Declination passing through the middle point between the stars. Both stars would then be seen in the field of view, and by small movements of the position-circle and of the slow-motion handles in R.A. and Declination, these images may be brought between the fixed position-angle wires (which mark the direction of measurement), and the measures can then be made by the movable wires with the greatest facility. The resulting measures are independent of any possible small motion of the prism relative to the axis of the telescope, and of any errors in the adjustment of the equatorial stand. The altitude of the stars can be deduced, with all necessary accuracy, by noting the time of each observation.

Convenient and simple as this observation may appear, it is subject to the objection that angles exceeding ten minutes of arc

cannot be measured by the spider-line micrometer with sufficient accuracy, when it is necessary that both objects be simultaneously bisected. The choice of objects for observation is thus limited to pairs of stars whose distance is equal to twice the angle of the prism $\pm 10'$ of arc. This objection could be overcome by the use of two eyepieces, or still better by the device of Alvan Clark, which, "by a convenient arrangement of prisms enables both webs, though separated one degree in a large telescope, to be seen in the same eyepiece." Unfortunately the latter arrangement is not described in detail by its author, and is said to be, as yet, somewhat troublesome to arrange previous to measurement, though, when arranged, it gives very good results.

2. An investigation of the elements of refraction on the preceding plan involves the construction of a complete special apparatus, but it becomes comparatively easy to adapt a modern heliometer to the purpose. It is only necessary to mount the prism in front of the object-glass, with the line of intersection of its reflecting planes at right-angles to the line of section of the segments of the object-glass and to the axis of the heliometer.

Observations can then be made by bringing the two images into coincidence in the centre of the field by symmetrical movements of the segments of the object-glass, as in the ordinary process of measurement with a heliometer. Unfortunately, by this method, angles smaller than twice the angle of the prism cannot be satisfactorily measured, but the large range of angle embraced by the heliometer makes this of little consequence. The chief drawback to the method is that when the objects do not differ much from 90° apart (that is, when the optical centres of the segments are nearly in coincidence) only one quarter of the whole area of the object-glass is available for seeing each star, and in order to give symmetry to the images at all distances it would probably be necessary to place diaphragms, shaped thus (fig. 2), on both segments of the object-glass.

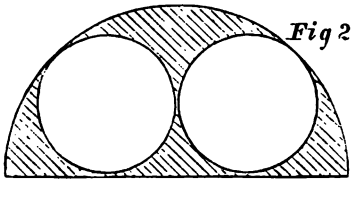

Fig 2

Thus with a heliometer object-glass of 4 inches aperture, the available aperture for seeing each star would correspond with that of an object-glass but little over $1\frac{1}{2}$ inch aperture. This, however, would permit accurate observation of stars to the 6th magnitude, and an ample selection of pairs of such stars would be available within the range of 88° and 90° in distance.

Royal Observatory, Cape of Good Hope:
1886, February 26.

Note on the Observations for Coincidence of the Collimators through the Cube of the Transit Circle at the Royal Observatory, Greenwich. By H. H. Turner, B.A., B.Sc.

For some time after the erection of this instrument, observations for coincidence of the Collimators could only be made after first raising the instrument, so that the view of one Collimator by the other was uninterrupted. In 1866 December, however, the central cube of the Transit Circle was perforated so that when the instrument was placed vertical a view of the South Collimator by the North could be obtained through eight holes of sector form, symmetrical about the common axis of the Collimators. The radial bars separating these sectors were not cut away in the hope of avoiding any serious interference with the rigidity of the cube, although this prevented the use of the central portions of the object-glasses of the Collimators in the observations. It was noticed soon afterwards that there was a small discrepancy between the readings for coincidence of the North Collimator on the South obtained when the Transit Circle was raised as before, and those obtained by this new method of viewing; but Sir George Airy, in commenting on it in his Report to the Board of Visitors in 1868, expressed some scepticism as to the reality of the discrepancy, and was more inclined to attribute the apparent discordance to "an erroneous habit in the application of the eye to the eye-glass, combined with a very small error of focal adjustment." The results of a number of observations in 1869 and 1870 were collected, however, and the mean difference of readings of the micrometer of the North Collimator was found to be $0^{r}\cdot020$ and $0^{r}\cdot024$ respectively, corresponding to $0''\cdot48$ and $0''\cdot58$. Experiments were made in 1872 November by two observers to test whether the position of the eye made any sensible difference in the reading for coincidence of the Collimators, but no such effect was discernible.

Accordingly from 1874, January 1, the discrepancy was accepted as real, and the reading obtained through the central cube was regarded as erroneous to that extent, owing to some cause not sufficiently explained; a correction of $0^{r}\cdot019$ (equivalent to a difference of $0^{r}\cdot023$ in the reading for coincidence of Collimators) being applied to the concluded reading for line of collimation of the Transit Circle micrometer.

The examination of the results of weekly observations in subsequent years confirmed this value of the correction as sensibly constant.

It still remained, however, to satisfactorily explain the discrepancy, and to determine whether the observations made with the Transit Circle raised had been correctly regarded as the standard. It seems very unlikely that the raising of the instrument produces an actual disturbance of either Collimator, for

the weight of the instrument is still borne by the pillars carrying the pivots. It was suggested

(*a*) That the change of position of such a large mass of metal might cause changes of temperature in the lower portions of the air of the room, and consequently changes in the refraction.

(*b*) That the discordance might be purely optical, either of the nature of diffraction, or due to a difference between the line of collimation of the edges of the Collimator object-glasses and that of the central portions.

As regards diffraction, the symmetry of the arrangement of the holes in the cube about the common axis of the Collimators would appear to obviate the possibility of an unsymmetrical discordance, such as that under consideration.

To discriminate between the other suggestions, in 1885 December a wooden model of the central cube of the Transit Circle was made which could, when the instrument was raised, be placed in the position usually occupied by the central cube, and the South Collimator could be viewed through the corresponding holes in the model cube. If the reading thus obtained for coincidence agreed with that when the instrument was raised and nothing interposed, it would seem that the discordance was due to differences of temperature, while an agreement with the reading taken through the ordinary cube would indicate that the phenomenon must be referred to the cutting off of the central portions of the object-glasses.

The following observations have accordingly been taken with this wooden cube:—

Date.	Observer.	Readings of North Collimator Micrometer. Transit Circle raised. Through the ordinary central cube.	Through wooden model cube.	Uninterrupted Vision.
		r.	r.	
1885, Dec. 28	H. T.	·508	·529	·465
		·526	·528	·467
1886, Jan. 6	L.	·490	·531	·481
		·493	·508	·487
Feb. 1	T.	·534	·550	·491
8	A. D.	·572	·557	·542
23	L.	·412	·400	·359
Mar. 8	A. D.	·419	·420	·398
15	H.	·553	·548	·503
22	A. D.	·501	·470	·452
Mean ...	... ...	·501	·504	·465

(The initials H. T., A. D., T., L., H. are those of Mr. Turner, Mr. Downing, Mr. Thackeray, Mr. Lewis, and Mr. Hollis respectively.)

It would thus appear that the readings obtained through the wooden model are sensibly the same as those obtained through the central cube in the ordinary manner, and that the discrepancy is due to a real difference between the lines of collimation of the central and excentric portions of the object-glasses of the Collimators; and the application of a correction to the "concluded reading for collimation," as deduced from an adjustment of the North Collimator through the cube, is accordingly justified.

With regard to the observations before 1874 which were not so corrected, Sir George Airy remarked that for clock stars and other fundamental stars near the equator, the effect of the correction was merely differential, and therefore almost insensible, and even for other stars is a small quantity.

It may be remarked generally that this investigation suggests that the use of excentric pencils of light in observations of this kind, without proper care, is liable to introduce unexpected errors.

On the Protuberances Visible on the Spectrum with a Narrow Slit.
By E. L. Trouvelot.

At the last meeting of the R.A.S., March 12, Mr. Maunder read a paper containing some criticism on a spectroscopic observation of mine, published in the January number of the *Bulletin Astronomique*. After having described the observation Mr. Maunder said: "I think it is sufficient merely to state this observation to show that there must be some mistake somewhere." Further on he continued: "But the most important thing is that he saw the prominence not only when the slit was open but when it was closed," and he concluded by saying that "the observation was evidently impossible."

If I understand correctly the objections, according to Mr. Maunder, the observation was impossible: 1st, because a protuberance having a certain height, say 3′ 37″, cannot be seen with a slit open wide enough to admit it; and, 2nd, because such a prominence cannot be seen whole with a narrow slit. I must confess that these objections, coming as they do from an experienced observer, have caused me quite a surprise, for the first phenomenon is not so difficult to detect even on ordinary occasions; and the second is not so rare that a diligent observer might not see it at least once or twice in the course of a year. That protuberances projecting upon the spectrum have not yet been seen by Mr. Maunder is quite possible, since these forms of prominences are rare and have usually a short duration; but I am at a loss to understand why he should have failed to see protuberances 3′ high with a wide-open slit, when I can see them so easily, for, I suppose, the instruments he uses for his observations are equal to mine. I will state that in ordinary circumstances—that is, when the sky is passably clear

and the prominences tolerably bright—I make my daily drawings of these objects with a tangential and wide-open slit, permitting the whole form to be seen at a glance. In this way I have often drawn prominences 3′ and 4′ high, and indeed I have sometimes thus recognised the complicated structure of protuberances having twice this height. Of course the brightness of these objects diminishes with the widening of the slit, and the conditions of seeing vary with the clearness of the sky, the brightness of the prominences, and the aperture and perfection of the instruments employed. But here we only refer to ordinary hydrogen protuberances, which are not very bright; while those seen on the spectrum, which all belong to metallic eruptions, are usually so very brilliant that their structure is very distinct with a wide-open slit.

The projection of large prominences on the spectrum, such as those of Sept. 10, 1872, and of June 26, 1874, are very rare, and they are indeed so much so that these are the only cases which came under my observation in a daily experience of fifteen years with the spectroscope; but the smaller forms of projections, having an elevation from 30″ to 60″, and even 80″, are not so rare, and on an average I have observed them two or three times every year. I am persuaded that if Mr. Maunder be cautious to cover his head with a veil, and allow a few minutes for his eye to get accustomed to darkness, he will see prominences with a wide-open slit as I do; and if he be assiduous and patient, it will not be a very long while before he sees a bright and well-formed protuberance on the spectrum, although the slit of his spectroscope will be narrow and almost closed. I do not know whether Mr. Maunder has founded his objections on any other grounds than those above quoted, and reported in the *English Mechanic* for March 19, p. 51, where I read them. But, supposing he has other reasons, I do not see that it would change anything in the observed phenomenon; the fact will remain unchanged. I think it would be quite surprising if the remarkable phenomenon I have observed for the last thirteen years, and described more than eight years ago, had not been seen by at least a few of the numerous observers looking daily at the Sun. If it has not, it may be expected that it will soon be recognised now that the attention of observers is awakened. As far as can be judged from the brief postscript added to the note of M. Tacchini, "sur la distribution en latitude des phénomènes solaires pendant l'année 1885," published in the *Comptes Rendus*, March 15, 1886, it would appear that the phenomenon in question has been recently recognised by this observer. The P.S. reads thus:—"Les 9 et 10 Mars courant, j'ai observé au bord ouest du soleil, des éruptions métalliques très-singulières, dont la matière projetée et tout à fait éblouissante rendait comme continue et très-vive une portion du spectre à partir de la raie C vers D, et l'apparence était celle d'une protubérance vue devant le spectre." On March 9, at 10 A.M., I observed a bright prominence situated at

261°, and following a group of Sun spots which passed on the other side the night before. This object, whose elevation was 2′, reversed a great number of metallic lines, and was so intensely brilliant that, with the slit over 2′ wide, it could be seen beautifully with all its complicated structure, not only on the hydrogen, magnesium, and helium lines, but also on the red line whose wave length corresponds to 6676·8 (?) It is very likely that it is in the vicinity of this object that the Italian observer saw the eruption above described, but he probably did not observe at the same time as I did, for although of a dazzling brilliancy, no projection on the spectrum except a slight deviation of the C line towards the violet end was seen at the time mentioned.

The following experiment made on the prominence form projected on the spectrum on Sept. 10, 1872, may have some interest, and will perhaps throw some light on the subject. The C line was made tangent to the Sun's border, just as shown on fig. 12 of my last Paper, only the slit was made so narrow that the C line appeared sharp and black. The narrowing of the slit did not prevent the protuberance remaining wholly visible on the spectrum, as I have said before. The telescope being clamped, and the clock in motion, the C line and Sun's limb kept relatively together during the experiment; then, by means of its proper screw, the slit was moved away from the Sun's limb, sliding along the prominence form from its base to its summit. As the slit advanced the lower part of the prominence became invisible, being hidden as it were by the portion of the spectrum situated on the less refrangible side of the C line, which was by no means diaphanous for it, like the portion on the opposite side of the same line. As the slit continued to advance, only the upper portion of the prominence situated on the most refrangible side of C remained visible, and it disappeared when the slit reached its summit. It is to be noticed that although the protuberance was bright on the spectrum, it was entirely invisible on the dark C line, except at one or two places where it was seen crossing this line, and even advancing a little on the spectrum towards the red end. The same phenomenon was also observed on the prominence of June 26, 1874, but then the displacement on the opposite side of the projection was at places quite considerable.

Whatever may be the cause of this singular phenomenon, which as a positive fact will stand, I am not prepared at present to discuss, but it is certain that, as far as my observations go, it agrees well with the theory attributing it to the motion of the source of light in the line of sight.

Note on M. Trouvelot's Paper. By E. W. Maunder.

It is to be regretted that M. Trouvelot did not wait until he had seen the actual text of my paper before replying to it, as the report on which he based his reply was a very inaccurate one. I did not call in question his ability to see the whole of a large prominence at once through a widely opened slit, nor even the possibility of his seeing an entire prominence projected on the spectrum. But I pointed out that one of his observations, taken as it stood, involved, according to the accepted interpretation of the displacement of lines in prominence spectra, that the prominence in question was moving with every conceivable velocity from rest up to 2,584 kilomètres per second. We cannot imagine the possibility of such a state of things, of a body being at one and the same time in a state of rest, of gentle motion, and of rapid motion; clearly either the observation must be incorrect, or the interpretation of it.

M. Trouvelot's present paper makes it clear, I think, that it is the observation that is in fault. Taken as it stands it amounts to the assertion that with a slit only a few seconds wide, and placed tangentially close to the Sun's limb, he was able to see an object nearly 2′ away from the limb, or much more than 1½′ outside his slit. In other words, that on occasion he is able to see a prominence through the solid metal of his slit-plate; or rather through one plate of his slit, for whilst one plate was diaphanous to the prominence the other remained opaque.

It is clear that there is some error in the report of such an observation. Probably, and this would account for the entire phenomenon, the slit, when M. Trouvelot tried to close it, refused to answer its screw, as slits will occasionally, and therefore remained fully open during the entire observation. However this may be, it is clear that any spectrum can only correspond to the light actually admitted through the slit, and that the displacement of lines *within* that spectrum cannot bring within the range of the slit objects that are placed far outside it.

For observations of displacements of the lines of prominences M. Trouvelot would find a narrow radial slit much preferable to a wide tangential one, and if instead of reversing his spectroscope as a check on his observations he had made his slit radial, he would at once have seen whether these marvellous displacements were real or not.

On the Semi-diameter of Venus. By W. G. Thackeray.

(*Communicated by Mr. Downing.*)

In the *Monthly Notices*, vol. xxv. p. 57, Mr. Stone has discussed the observations of *Venus* with the Greenwich Mural and Transit Circles for the years 1839–62. Assuming that the error arising from personality is sensibly eliminated when the number of observers is considerable, and that it is practicable when the number of observations are sufficiently numerous to separate the constant part of the diameter due to the instrument from the part which varies with every change in the planet's distance, he obtained a correction to be applied to the *N.A.* semi-diameter when a single limb only was observed—

$$\text{viz. } +0''.392 \quad +(0.0269 \times \textit{N.A.} \text{ semi-diameter.})$$

a correction which has been applied to the Greenwich observations when needed up to the present time. In 1865 Encke's value (8″·305) of the semi-diameter at the mean distance of the Sun from the Earth was used in the *Nautical Almanac*, instead of the value previously used, 8″·250. Let 8″·305 $(1+y)$ be the true semi-diameter, and let x be the constant quantity by which the computed diameter would require to be corrected to agree with the observed diameter. Then, $x+(1+y)$ *N.A.* diameter = observed diameter. Taking the values of the *N.A.* and observed vertical diameters, as given in the planetary results of the Greenwich observations for the years 1866–84, and separating the observations into two classes, those above 20″ and those below 20″ in diameter, by simple summation, we get two equations for the determination of the values of x and y:—

$$302x + 10192{\cdot}2y = 431{\cdot}66$$
$$590x + 7629{\cdot}4y = 757{\cdot}75$$

from which we obtain

$$x = +1''.196 \pm$$
$$y = +0.0067 \pm$$

This gives the value of the semi-diameter at the mean distance of the Sun from the Earth = 8″·360, and the correction to be applied in the case of a single limb being observed becomes

$$+0''.598 + (0.0067 \times \textit{N.A.} \text{ semi-diameter}).$$

Now let us assume that the error of personality is not sufficiently eliminated by the number of the observers, and only use

the observations made by the four regular observers at the present time, we then get

		Above 20″.	Below 20″.
A. D.	(1873–84)	$25x + 742{\cdot}5y = 46{\cdot}27$	$70x + 891{\cdot}1y = 112{\cdot}79$
T.	(1875–84)	$19x + 611{\cdot}8y = 29{\cdot}07$	$59x + 758{\cdot}6y = 43{\cdot}91$
L.	(1881–84)	$18x + 570{\cdot}3y = 13{\cdot}23$	$11x + 130{\cdot}8y = 2{\cdot}71$
H.	(1882–84)	$5x + 177{\cdot}4y = 14{\cdot}21$	$20x + 254{\cdot}3y = 13{\cdot}87$
		$67x + 2102{\cdot}0y = 102{\cdot}78$	$160x + 2034{\cdot}8y = 173{\cdot}28$

from which we obtain

$$x = + 0''{\cdot}776 \pm$$
$$y = + 0{\cdot}0241 \pm$$

This gives semi-diameter at the mean distance of the Sun from the Earth 8″·505, and the correction to be applied to a single limb becomes +0″·388+ (0·0241+*N.A.* semi-diameter), a correction which happens to agree very closely with the one at present applied. Now, considering that the first set of equations refer to a considerable number of observations and observers, it would seem that the value of x is not independent of the error of personality, and that the value of y does vary with the change in the planet's distance; and if we solve the different equations referring to the different observers, we get

		Mean Semi-diameter.
For A. D.	$x = + 1''{\cdot}432 \pm$, $y = + 0{\cdot}0141 \pm$	8″·422
T.	$x = + 0{\cdot}180 \pm$, $y = + 0{\cdot}0426 \pm$	8·659
L.	$x = - 0{\cdot}049 \pm$, $y = + 0{\cdot}0248 \pm$	8·511
H.	$x = - 0{\cdot}506 \pm$, $y = + 0{\cdot}0943 \pm$	9·088

From these values it would appear that the amount of personality involved in the observation is much greater than the correction due to the instrument; and that, though a greater number of observers may be likely to give a more accurate value and compensate one another, it is just as likely that they should not.

On the Orbit of α Centauri. By E. B. Powell.

In two papers, published respectively in the *Monthly Notices* for November 1884 and March of the current year, I have assigned grounds for the conclusion that a period of some 76 years will not satisfy the imperfect observations of α *Centauri* taken in past centuries, and those made with fixed instruments in the early portion of the present one, and that a time of revolu-

tion of 86 years or upwards is required for this purpose. I now do myself the pleasure of laying before the Society a set of elements for that binary, with a period somewhat exceeding 87 years, which appear to satisfy fairly the recorded equatorial measures.

The calculations made by me upon the subject have been rather numerous. After arriving at an orbit which afforded a moderately fair representation of the motion from 1834 to 1884, eighteen epochs were selected as giving measures of apparently very considerable accuracy, and at the same time pertaining to telling points in the perspective ellipse. Variations of position-angle were then found for variations in the elements corresponding to the selected epochs; and, finally, equations of condition were formed and solved by the method of least squares. By taking at first some of the elements, P, τ and e for example, finding and applying the corrections thus afforded, and then determining the corrections of the remaining elements from the residual errors, orbits differing slightly were arrived at. The corrections of all the elements were also found simultaneously. In no case did P come out less than 86 years, and in only one was a considerably greater value obtained; this last value, which was afforded by the simultaneous solution of the equations for all the elements, I considered inadmissible for reasons connected with the early notices of the star, though the set of elements to which it belonged somewhat reduced the magnitude of the differences between observation and calculation for the eighteen epochs. Ultimately the elements given below were adopted. Of these, P and τ were obtained from ten equations of mean motion formed by combining different pairs of measures corresponding to considerable intervals of time, no interval being less than 25·8 years. The different values of P and τ thus found agreed well with one another, only one value of P falling so low as 86 years, two slightly exceeding 88, and the rest lying between 87 and 88 years. The remaining elements were determined by applying the method of least squares to the variation equations, using the residual errors of position after correcting for P and τ. Finally, the semi-major axis was found from eighteen measured distances. The extreme values were 19″·287 and 18″·259; the mean of the whole is the value adopted.

Elements.

$P = 87{\cdot}438$ years.

$\tau = 1875{\cdot}447$.

$e = {\cdot}544326$.

$\gamma = 79^\circ\ 47'\ 8''$.

$\Omega = 25^\circ\ 49'\ 38''$.

$\lambda = 48^\circ\ 59' - 17''$, $\tilde{\omega} = 37^\circ\ 21'\ 9''$.

$a = 18''{\cdot}89$.

It may be noticed that, along with an increase of P, besides obtaining a larger value of a, we get an earlier time of periastron passage and an augmentation of the eccentricity.

Comparison of Observation with the results afforded by the above Elements.

Observer.	Epoch. 1800+	θ_o °	d_o "	$\theta_o - \theta_o$ °	$d_o - d_o$ "
Herschel	34·790	218·55	17·4	− ·72	−·41
Herschel	37·345	220·73	16·20	− ·48	·00
Jacob	47·090	235·10	9·45	− ·39	+·38
Jacob	48·010	238·00	8·03	− ·15	−·33
Maclear	50·313	247·07	6·75	− ·19	+·12
Maclear	51·565	254·42	5·88	− ·02	+·12
Maclear	52·793	263·31	4·99	− ·48	·00
Maclear	53·503	271·03	4·68	+ ·52	+·05
Jacob	54 391	281·38	4·30	+1·03	+·03
Powell	54·631	283·47	—	+ ·19	—
Powell	55·047	289·05	4·12	+ ·46	+·03
Maclear	55·357	291·96	4·38	− ·75	+·35
Maclear	56·022	302·13	3·95	+ ·31	−·03
Jacob	56·209	304·24	4·02	− ·77	+·04
Jacob	56·922	315·30	3·96	+1·20	−·10
Maclear	57·390	320·60	4·47	+ ·44	+·30
Jacob	57·991	327·49	4·24	+ ·08	−·12
Jacob	58·272	330·60	4·38	+ ·05	−·10
Maclear	59·228	339·42	5·09	− ·62	+·15
Maclear	60·183	349·34	—	+1·60	—
Maclear	60·346	348·87	5·59	− ·03	−·01
Powell	60·479	348·70	5·60	−1·11	−·08
Maclear	61·090	353·65	6·09	− ·03	+·01
Powell	62·205	358·00	6·79	−1·56	−·04
Maclear	62·560	1·38	7·55	+ ·21	+·48
Powell	63·028	1·40	7·20	−1·73	−·19
Ellery	63·750	5·20	8·50	− ·64	+·63
Powell	64·110	5·7	7·85	−1·37	−·26
Powell	66 063	11·10	9·30	−1·61	+·01
Powell	70·100	20·45	10·24	− ·95	−·27
Russell	70·746	22·32	10·46	− ·37	+·03
Powell	71·310	23·70	9·80	− ·14	−·46
Russell	72·468	25·33	9·73	−1·05	+·11
Russell	73·331	28·07	9·50	− ·52	+·66

Observer.	Epoch. 1800+	θ_o °	d_o "	$\theta_o - \theta_o$ °	$d_o - d_o$ "
Ellery	74·150	30·50	8·00	− ·66	+·16
Lindsay	74·850	34·17	—	+ ·14	—
Seelinger	75·020	34·21	6·82	− ·66	+·31
Russell	76·411	46·97	4·35	+ ·43	+·39
Ellery	76·615	51·05	4·15	+1·35	+·58
Maxwell Hall	77·140	64·40	3·30	+2·34	+·69
Russell and Gill*	77·602	81·46	1·97	− ·95	+·03
Gill	77·848	97·57	1·79	−1·18	+·07
Maxwell Hall	78·380	139·10	2·4	+ ·65	+·56
Ellery	79·252	174·40	3·41	+1·70	+·21
Tebbutt	80·186	186·70	4·97	+1·23	−·05
Tebbutt	81·655	193·15	7·95	− ·40	+·09
Gill and Elkin	83·500	198·00	10·70	− ·14	−·37
Tebbutt	84·533	199·80	12·93	+ ·05	+·27
Tebbutt	85·580	201·02	14·20	− ·01	+·06

In testing the elements, all the available observations have not been used. It seemed to me that the number taken, spread as they are over the whole circuit, would suffice to give a correct idea of the degree of correspondence between the orbit and observation. A comparison has not been made in the case of the Sydney observations subsequent to 1877, since it appears, as Mr. Downing has observed, that some influence must have operated to throw out these measures from accord with those taken at other Observatories. It also seemed that no object would be attained by introducing the Melbourne observation for 1876·94 into the comparison, as the position-angle is practically the same as that given by the observation at the same place for 1876·615, while the motion of the comes during the interval must have been about 6°; for the earlier date also there are two sets of position-measures, while for the later there is only one. In two or three cases, where an observer did not take a measure of distance contemporaneously with his position-measure, but observed the distances for closely adjacent epochs, the distance for the epoch belonging to the angle has been found by proportion.

I may remark that the orbit now submitted agrees fairly with the notices of the binary in past centuries, with the exception of Maskelyne's observation of distance, and La Caille's measures of Diff. Declination and Diff. Right Ascension; it also accords with the Declination measures of the early part of this century, save in the case of Fallows. The disagreement in these instances, as was urged in my recent Papers on the period of *α Centauri*, cannot well be held of much weight.

* Russell ·596, 81°·7, 1″·9; Gill ·609, 81°·23, 2″·02.

In conclusion, while I consider that the evidence is tolerably strong against the period of this binary being only some 76 years, I by no means assert that the time of revolution is precisely 87·438 years. I hold that several years of observation will be required to fix quite accurately the values of P, τ, and e; but, from the annexed Table, I think it is evident that in six or eight years, if careful measures be taken, the point will be settled as to whether the period is about 76 years or exceeds 86 years.

Epoch.	Downing-Elkin Orbit. P. °	d. "	Orbit now submitted. P. °	d. "
1886·275	202·61	14·89	201·74	15·04
1889·275	205·16	17·70	204·10	18·30
1892·275	207·11	19·52	205·82	20·68
1895·275	208·79	20·54	207·24	22·33
1898·275	210·37	20·91	208·49	23·39
1901·275	211·93	20·74	209·65	23·93

Hampstead: April 1886.

The Magnitude of η Argûs in March 1886.

By W. H. Finlay, M.A.

I have examined the magnitudes of the stars in the neighbourhood of *η Argûs*, and compared them amongst themselves on several occasions recently, with the following result:—

The letters used to denote the stars are those given by Sir John Herschel on pp. 44–46 of his "Results of Astronomical Observations at the Cape of Good Hope." My observations for the magnitude of *Eta* (A) are

$$\mathrm{A}\begin{cases} = \mathrm{F} \\ = \mathrm{F} \\ \text{slightly} < \mathrm{F} \end{cases} \quad \begin{cases} < \mathrm{O} \\ < \mathrm{O} \end{cases} \quad \begin{cases} > \kappa' \\ = \kappa' \end{cases} \quad \begin{cases} > \mathrm{C} \\ \tfrac{1}{2}\ \text{mag.} > \mathrm{C} \end{cases} \quad \begin{cases} \text{slightly} < \beta. \end{cases}$$

I also note *β very* slightly $< \lambda$.

The magnitudes of these stars, as given by Herschel himself and by Gould in the Cordoba Catalogue, are

	Herschel.	Gould.	
F	8	8	
O	7	7½	
κ′	8	8	whence η is not very different from 7½ magnitude.
C	8	—	
β	8	7½	
λ	7	7½	

The stars F, β and λ, however, are among those whose magnitudes were specially determined by Gould for comparison with [illegible] (*Uranometria Argentina*, p. 256), and they are there given as [illegible]·48, and 7·44 respectively. As they have maintained [illegible] relative magnitudes, we may assume the actual magnitudes [illegible]e still the same; and my observations, therefore, make the [illegible]gnitude of η *Argûs* at the present time very approximately

7·6

in Gould's scale of magnitudes.

Royal Observatory, Cape of Good Hope:
1886, *March* 16.

The Nebulæ in the Pleiades. By A. A. Common.

The photograph of a part of the *Pleiades*, by MM. Henry, referred to in their letter to Mr. Knobel in the last number of the *Notices* of the Society, is very interesting. That MM. Henry set out with the intention of photographing the nebula near *Merope*, that is so well known, may be taken for granted; that they should evidently fail to get this, and get evidence of three separate nebulæ all near bright stars, only one of which can be said to have been certainly seen before, this being the same one near *Merope* that I found with the 3-foot Reflector in 1880 (*Monthly Notices*, April 1880), is very remarkable, and is due to the greater power of the photographic method over the eye in recording the presence of a faint light in the neighbourhood of a bright one.

On referring to my note of the observation of the small nebula near *Merope*, I have said: "There is strong suspicion in my mind of more nebula here," and I mention, "a similar appearance elsewhere" to that of this nebula. This I believe alluded to an observation of the Maia nebula which will be doubtless easily seen in the 3-foot telescope, and was the cause of the observation in the last paragraph of my note, where I say there is a great deal yet to be settled as to the extent and number of the nebulæ in this cluster.

Whether the fainter well-known nebula can be photographed with a telescope so small as that used by MM. Henry remains to be seen. There is an extremely small amount of light available, the light of this nebula being, I believe, not so bright as the zodiacal light at a considerable elevation, whilst the faintest trace of skylight quite obliterates it. Observations made at this time of year would, I feel sure, render it very doubtful if this nebula could be seen with any aperture, and it may be that this would account for it not being seen by some observers who have only looked for it at this time of the year.

Introduction to a Catalogue of the Colours of 1,730 *Stars.*

By W. S. Franks.

The observations detailed in the Catalogue of Star Colours, herewith presented to the Society,* were commenced on Oct. 31, 1884, and continued until March 10, 1886. Two telescopes were employed, both of them Newtonian reflectors, and equatorially mounted—the specula, by Calver, of $11\frac{1}{4}$-inch and $5\frac{1}{4}$-inch aperture, with foci of 80 inches and 40 inches respectively. The smaller instrument was reserved for stars between $+54°$ and the Pole, which the larger telescope, from its peculiar style of mounting, could not reach. The eyepieces used were of the "Kellner" construction, giving powers of 90 and 200 on the $11\frac{1}{4}$-inch, 45 and 100 on the $5\frac{1}{4}$-inch; the lower power had a field of 40′ on the former, and 1° on the latter instrument. The higher power was only used for *double* stars. The magnitudes provisionally employed were derived from Heis, and, on the whole, they were found to be fairly accurate. A few obvious discrepancies were, however, met with, and duly recorded in the column headed "Remarks"; though particular attention to magnitude determinations was scarcely thought of, after the elaborate photometric researches so recently undertaken by Professors Pickering and Pritchard. All stars down to the 6–5 magnitude of the *Atlas Cœlestis Novus* (between $-20°$ and $+90°$) were examined, besides a few others of 6 magnitude, which were added during the prosecution of the work, being, in most cases, such as were in the immediate vicinity of the objects under examination. The constellation boundaries adopted were also from Heis, and in such instances where they differed from those of the B.A.C., a note to that effect was inserted under "Remarks." Every star common to the present catalogue and the previous one (1877-8) has been compared, and where any serious difference was detected the same was duly entered in its proper place. Some of the violent discordances alluded to may probably be due to defective identification, the 1877-8 series having been taken directly from the atlases of Proctor and the S.D.U.K., and the finder as often used in the search as the circles. But, in the present list, every star has been separately identified by circle readings; and it is therefore likely to be the more trustworthy of the two series. On the whole, however—and considering that the two sets were made with telescopes of different construction, with a wide difference in aperture—the old and new observations are fairly accordant, and within the usual limit of error.

In connection with the subject of star colours it may be worth remark that many stars were found to be distinctly *yellower* in twilight than on a dark sky; also that slight fog or haze had the effect of intensifying the yellow tints, especially, of course, towards the horizon. And, further, when collating the

* The Catalogue is placed in the Library.

present observations with those made in 1877–8 (Catalogue of 3,890 Stars) a systematic difference was clearly manifested, inasmuch as the 11¼-inch reflector made most objects with a yellow or orange tint distinctly *paler* than they were seen with the 5-inch achromatic—apparently due to the difference in the light-grasping power of the two telescopes, rather than to their different construction. From a careful series of comparisons which I made some years ago, between a refractor and reflector mounted side by side, with the apertures arranged so as to be precisely equivalent, I do not believe there is any appreciable difference between the colour results given by a reflector and a well-achromatised refractor of similar light-grasping power. On comparing the percentages given in the Appendix to the Catalogue (Table 2), it will be seen that, out of a total of 52 constellations, 42 show a *higher* percentage of "white" stars, and 36 a *lower* percentage of "orange" stars, for the 1884–6 than for the 1877–8 series. This and the preceding facts seem to point to the conclusion that the *colour* of stellar light is affected, to a certain extent, by its intrinsic *brightness* also. And another circumstance, which does not appear to have hitherto attracted attention, tends to confirm this view. It is that those constellations having many *bright* stars are, as a rule, remarkable for their high percentage of "white"; whilst in those constellations where there are many *small* stars, and relatively few bright ones, the "yellow" and "orange" tints are most abundantly found. The question of colour distribution in the sidereal heavens has, so far, received but scant attention from astronomers, notwithstanding the interesting nature of the inquiry, and that it might be made to yield important evidence respecting the constitution and structure of the stellar universe. It is a fact worthy of remark that most of the constellations with a high percentage of *white* stars, such as *Cassiopeia*, *Perseus*, *Taurus*, *Orion*, *Scorpio*, *Lyra*, &c., are associated with the galaxy. The late Prebendary Webb had noticed the absence of coloured stars as regards *Taurus*; and Padre Secchi, from spectroscopic observations, found that stars with spectra of the first (Vega) type prevailed in *Lyra*, *Taurus*, and *Orion*. The latter observer also remarked that the second (Aldebaran) type was abundant in *Cetus*, *Cepheus*, *Draco*, *Eridanus*, &c.; but the last-named constellation is, according to my observations in 1877–8 and 1884–6, rather remarkable for "white" than "yellow" stars. The *yellow* and *orange* coloured stars appear to be generally most plentiful in large straggling constellations, such as *Cetus*, *Pisces*, *Hydra*, *Leo*, *Virgo*, *Boötes*, *Draco*, *Aquila*, &c.; whilst the rich compact asterisms are distinguished for their number of *white* stars. Beyond this it does not seem possible at present to indicate any general law that governs the distribution of stellar colours, though it is much to be desired that with a better means of registering star tints than is afforded by mere eye-estimation, some effort should be made in the future to throw light upon this interesting though obscure

point. As illustrating the fact, previously referred to, of the systematic discordancy between the colour estimates of 1877–8 and 1884–6, the Appendix shows that the *mean* percentage of white, yellow, and orange stars is as follows:—

55·2	white,	35·2	yellow,	9·6	orange,	from 1,744	stars in	1884–6	catalogue.	
48·6	,,	36·8	,,	14·6	,,	,, 1,641	,,	,, 1877–8	which are common to both lists.	
46·0	,,	38·1	,,	15·9	,,	,, 3,816	,,	,, 1877–8	catalogue.	

As the larger number of stars in the 1877–8 series confirms the smaller number common to both lists, it is evident that, in any future observations the *aperture* of the telescope will have to be considered as a modifying factor in the final result.

A few words of explanation will suffice respecting the arrangement of the present catalogue. Instead of the usual arbitrary order in R.A., which could give but little idea of the grouping of colours in particular regions of the heavens, the stars are arranged in *constellations*, according to the "Index-plan;" from which it will be seen that they are divided into twelve groups, each group commencing at the southern limit and ending at the most northern. This was done, in the first place, for convenience in observing; and it has been retained because it seemed an improvement over the older plan. No difficulty need arise in finding any required object, since the constellation page is there given, and the stars in each constellation are in R.A. order. In addition to the "Symbols and Abbreviations" given on the same page as the Index-plan, a few others have been employed, as follows: "brt."=bright; "wh."=white; "blsh."=bluish; "grnsh."=greenish; "yelsh."=yellowish; "yel."=yellow; "or."=orange. And the "Explanation of Terms used in designating Star Colours" may be of service in giving a more precise definition of the intended meaning. Column I. of the catalogue gives the *name* of star; column II. its *number* in the "British Association Catalogue;" columns III. and IV. the *R.A.* and *Decl.* for epoch 1880 (these are approximate merely, but quite sufficient for identification); column V. gives the *magnitude*, from Heis' "Catalogus;" column VI. the *colour*, as observed with the 11¼-inch or the 5¼-inch telescope; column VII. the *date* of observation, together with *remarks*—the magnitudes in this column, when following a "double" or "triple" star, are from Struve's "Mensuræ Micrometricæ."

The positions of 1,730 stars are given in the catalogue, but the total number of stars included is 1,893, the balance being due to the *comites* of multiple stars. Some 72 stars, chiefly from Bode and Lalande, appear in this catalogue for the first time; all the others are contained in my former list of 3,890 stars (1877–8). The "double" stars were, as a whole, observed before the others; this being part of a previously arranged survey of all the sidereal portion of Webb's "Celestial Objects."

As considerable care was devoted to these double stars it was thought advisable to include the *colours* of their *comites* in the present list—at least, such as were above 9 mag.

The "Appendix" contains a table, giving an analysis of all the colours of the 1,893 stars (reproduced at the end of this paper); and a second table, in which the percentage of "white," "yellow," and "orange" stars only, is given. For the purpose of comparison, the percentage results of the stars common to the catalogues of 1877–8 and 1884–6, and also those obtained from the whole of the stars in the former catalogue, are appended. An attempt has been made on the map which accompanies the catalogue to give a graphic delineation of the manner in which the white, yellow, and orange stars are distributed in the N. hemisphere; it includes about 1,400 stars.

Analysis of the Colours of Stars contained in the Catalogue (Table I., Appendix).

Constellation.	White.	Yellow.	Orange.	Red.	Green.	Blue.	Purple.	Others.	Total.
Cetus	23	18	4	—	—	1	2	—	48
Pisces	15	28	6	2	—	1	—	—	52
Andromeda	21	15	4	—	1	—	—	—	41
Cassiopeia	25	15	2	1	—	2		1	48
Eridanus	20	10	5	—	1	—	—	—	36
Aries	26	10	—	1	—	1	1	—	39
Triangula	7	6	—	—	1	—	—	—	14
Taurus	50	13	4	—	1	3	4	—	75
Perseus	31	14	5	—	—	2	1	—	53
Lepus	7	3	—	—	1	—	—	—	11
Orion	44	10	4	1	—	6	2	—	67
Auriga	18	13	5	—	—	1	3	—	40
Camelus	25	10	4	—	—	3	1	—	43
Canis Major	7	4	2	—	1	—	—	—	14
Monoceros	24	8	3	—	—	1	1	1	38
Canis Minor	5	4	1	—	—	2	—	—	12
Gemini	21	15	3	—	—	1	3	—	43
Lynx	12	5	—	1	—	—	3	—	21
Argo Navis	6	—	1	—	—	1	—	—	8
Hydra	10	9	4	2	—	—	1	—	26
Cancer	16	13	3	—	1	2	—	—	35
Leo Minor	9	7	2	—	—	—	—	—	18
Sextans	6	1	—	—	—	—	—	—	7
Crater	3	5	1	—	—	—	—	—	9
Leo	25	20	14	1	—	2	4	1	67

Constellation.	White.	Yellow.	Orange.	Red.	Green.	Blue.	Purple.	Others.	Total.
Ursa Major	40	27	4	—	1	2	2	—	76
Corvus	5	1	—	—	—	—	1	—	7
Virgo	22	20	3	—	—	1	—	—	46
Coma Berenices	10	12	2	—	—	—	3	—	27
Canes Venatici	12	7	7	—	—	1	—	1	28
Libra	8	5	—	—	—	—	—	—	13
Boötes	29	23	4	—	—	1	6	—	63
Corona Borealis	10	9	2	—	—	1	1	—	23
Ursa Minor	8	7	1	—	—	—	—	—	16
Scorpio	7	2	—	—	—	1	1	—	11
Serpens	16	12	2	—	—	—	—	—	30
Ophiuchus	23	14	2	—	—	—	1	—	40
Hercules	47	23	12	—	2	—	1	—	85
Draco	40	32	9	—	—	4	3	—	88
Sagittarius	5	3	—	—	—	—	—	—	8
Aquila	28	22	3	—	—	—	1	—	54
Sagitta	3	5	1	—	—	1	—	—	1
Lyra	16	10	1	1	—	2	—	1	31
Capricornus	10	7	3	—	—	2	—	—	22
Delphinus	8	5	—	—	1	—	1	—	15
Equuleus	1	6	—	—	1	1	1	—	10
Vulpecula	16	9	2	—	—	1	—	-	28
Cygnus	45	29	10	—	3	6	3	2	98
Aquarius	29	17	4	—	—	3	2	—	55
Pegasus	28	30	11	—	—	—	1	—	70
Lacerta	12	3	5	—	—	—	—	—	20
Cepheus	28	18	3	—	—	3	2	—	54
Grand Total	962	614	168	10	15	59	58	7	1,893

Note on the Radiation of Meteors. By W. F. Denning.

In a short paper on the Biela meteors (*Monthly Notices*, Jan. 1886, p. 118) Mr. Proctor remarks that the diffuse character of the radiation "appears unquestionably due to changes of direction caused by atmospheric resistance," and then hastily assumes that a radiant-area of two degrees diameter cannot "safely be assigned to meteors having the so-called stationary radiants."

But Mr. Proctor quite misses the fact that these meteors of Biela's comet enter the atmosphere at the rate of only about eleven miles per second, while the apparent velocities of the very great majority of the other known meteor streams must average

at least thirty miles per second. The effects of air resistance in deflecting the courses must be vastly less, in the case of these swifter meteors, than that affecting the exceptionally slow meteors falling from γ *Andromedæ* on Nov. 27, where such disturbances will evidently reach a maximum. The nature of the radiation observed in regard to the latter is special* and cannot for a moment be supposed to represent that of meteor swarms generally. The shooting stars belonging to ordinary and fairly typical showers exhibit radiants confined to very limited areas; for in cases where the individual flights are recorded with great accuracy they are invariably found to intersect nearly at a point.

As to the stationary radiant points, which I confidently uphold as the unavoidable outcome of my observations, they cannot be obliterated from the sky but by more effectual objections than that such anomalies are not moulded according to the theories which have been imperfectly applied to a branch of astronomy of very modern date. If these radiants are inexact, or if a wrong construction has been put upon their singular affinities of grouping, the fact may be determined by further observation. We are not yet in a position to assume that our knowledge of theory comprehends every possible form and condition of meteoric phenomena presented to the earth.

I cannot but feel indebted to Mr. Proctor for his frequent references to this subject, for it is likely to suffer most by that indifference and apathy with which complex details of observation are too often treated. But he will do best service by enforcing on observers the necessity of subjecting the disputed features to further critical investigation rather than by raising obstacles, many of which have no weight. We require not only careful re-determinations of the radiants, but new and reliable data as to the velocity of meteors. I believe that the tendency in past years has been to overestimate the durations, and that, were the records true to fact, many instances of hyperbolic fireballs (with their associated currents of small meteors) would have resulted from the computations. But though the speed, in certain cases, may have exceeded that which has been assigned, it is scarcely possible it can have been so great as that which Mr. A. C. Ranyard and others have pointed out as necessary to explain the occurrence of meteors from fixed, long-enduring radiants.

Bristol: March 15, 1886.

* Its diffuseness is admitted, but the meteors are so numerous that the central radiants, as deduced by different observers (many of whom may claim little experience in determinations of this sort), are in excellent agreement. See the comparative table of positions for the shower of November 27, 1885, compiled by the writer for the *Astronomical Register*, April 1886, pp. 95–6.

Observations of Comets d, 1885 (Fabry), and e, 1885 (Barnard), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations on March 11, March 23, April 1, and April 3, were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, and those on March 9 with the Lassell Reflector, aperture 24 inches, by taking transits over two cross-wires at right-angles to each other, and each inclined 45° to the parallel of Declination.

Comet d, 1885.

Greenwich Mean Solar Time. 1886.	Observer.	☄−★ R.A.	Corr. for Par. & Refract. in R.A.	☄−★ N.P.D.	Corr. for Par. & Refract. in N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
d h m s		m s	s	′ ″	″		h m s	° ′ ″	
March 11 7 43 47	L.	+0 31·13	+0·16	+10 8·5	− 2·2	6	23 19 1·24	57 32 30·0	*a*
April 3 8 22 45	H.	−3 16·37	+0·03	− 6 25·6	−19·3	3	23 19 50·18	50 53 21·2	*b*

Comet e, 1885.

March 9 9 11 17	H. T.	+0 28·38	+0·24	− 0 26·5	− 3·9	4	1 54 15·62	66 41 56·5	*c*
23 8 40 49	H. T.	+0 8·08	+0·19	+ 7 5·0	− 2·8	5	1 51 38·96	62 9 18·5	*d*
April 1 8 39 8	H. T.	+1 2·75	+0·24	+ 1 19·4	− 3·9	4	1 50 16·67	58 56 31·5	*e*
3 9 16 39	H.	+0 41·77	+0·16	+ 2 42·0	− 2·9	3	1 49 51·72	58 10 47·1	*f*

Mean Places of Comparison Stars.

	Star's Name.	R.A. 1886·0. h m s	N.P.D. 1886·0 ° ′ ″	Authority.
(*a*)	W. B. (2) XXIII. 346	23 18 30·74	57 22 20·6	Weisse's Bessel (2).
(*b*)	W. B. (2) XXIII. 457	23 23 7·09	50 59 59·3	Weisse's Bessel (2).
(*c*)	Arg. Zone, +23° No. 266	1 53 47·45	66 42 22·3	Bonn Observations, Vol. IV.
(*d*)	W. B. (2) I. 1168	1 51 31·25	62 2 13·1	Weisse's Bessel (2).
(*e*)	Arg. Zone, +30° No. 298	1 49 14·28	58 55 10·3	Bonn Observations, Vol. IV.
(*f*)	W. B. (2) I. 1095	1 49 10·41	58 8 2·2	Weisse's Bessel (2).

Notes.

March 9. (*e*). Comet near Moon, but easily seen in finder.
March 11. (*d*). Comet very bright; a slight condensation to right of centre. No tail visible.
April 3. (*d*). Comet very bright.

The observations are corrected for parallax and refraction. The initials HT., L., and H., are those of Mr. Turner, Mr. Lewis, and Mr. Hollis respectively.

Errata in Monthly Notices, Vol. xlvi. *p.* 303.

In column "Corr. for Par. and Refract. in N.P.D.," *for* $-4''\cdot1$, $-2''\cdot5$, $-4''\cdot6$, *read* $-5''\cdot4$, $-3''\cdot8$, $-6''\cdot1$, respectively.

In column "Apparent N.P.D.," *for* $58^\circ\ 43'\ 15''\cdot8$ *read* $58^\circ\ 43'\ 14''\cdot5$.
„ 58 43 20·2 „ 58 43 18·9.
„ 58 43 8·9 „ 58 43 7·4.

Royal Observatory, Greenwich: 1886, *April* 9.

Observations of Occultations by the Moon, 1884–5, and of Eclipses of the IVth Satellite of Jupiter, 1885, made at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

Occultations by the Moon.

Ref.	Day of Obs.	Phenomenon.	Moon's Limb.	Instrument.	Power used.	G.M.T. of Observation. h m s	Observer.
	1884.						
(*a*)	July 3	Disapp. ζ Libræ	Dark	Equatorial	125	8 54 6·7	R.
(*b*)	Oct. 12	Reapp. 60 Cancri	,,	,,	110	17 30 14·5	R.
(*c*)	,,	Disapp. α Cancri	Bright	,,	,,	17 59 17·3	R.
(*d*)	Dec. 4	Reapp. λ Geminorum	Dark	,,	125	16 41 28·4	F. B.
	1885.						
(*e*)	Jan. 21	Disapp. B.A.C. 57	,,	,,	,,	5 37 45·3	R.
(*f*)	Feb. 20	Disapp. 38 Arietis	,,	Heliometer	200	7 41 10·9	W.
(*g*)	,,	,, ,,	,,	Equatorial	125	7 41 11·3	R.
(*h*)	,,	,, ,,	,,	Marlborough	80	7 41 11·0	F. B.
(*i*)	March 27	Disapp. B.A.C. 3529	,,	Equatorial	125	10 21 43·6	R.
(*j*)	,,	Disapp. 43 Leonis	,,	,,	,,	11 34 14·4	R.
	April 20	Disapp. λ Geminorum	,,	Dollond	80	10 58 3·8	R.
(*k*)	22	Disapp. B.A.C. 3122	,,	Equatorial	125	9 2 3·6	R.
(*l*)	,,	,, ,,	,,	Heliometer	200	9 2 3·3	F. B.
(*m*)	July 8	Disapp. Aldebaran	Bright (Near Mid-day)	,,	80	23 21 40·9	W.
(*n*)	,,	,, ,,	Bright	Equatorial	45	23 21 41·0	R.

Ref.	Day of Obs. 1885.	Phenomenon.	Moon's Limb.	Instrument.	Power used.	G.M.T. of Observation. h m s	Observer.
(*o*)	July 20	Disapp. o^2 Libræ	Dark	Equatorial	45	10 55 38·4	R.
(*p*)	22	Disapp. 29 Ophiuchi	,,	,,	,,	10 28 40·1	R.
(*q*)	Sept. 1	Reapp. B.A.C. 1391	,,	Heliometer	80	11 31 58·5	W.
	,,	,, ,,	,,	Marlborough	,,	11 31 60·0	F. B.
	,,	Reapp. 85 Tauri	,,	Heliometer	45	12 3 33·3	W.
(*r*)	19	Disapp. 13 Capricorni	,,	Equatorial	125	8 2 33·5	F. B.
(*s*)	,,	Disapp. 14 Capricorni	,,	,,	95	9 32 13·3	F. B.
(*t*)	21	Disapp. B.A.C. 7774	,,	Heliometer	45	10 6 29·3	W.
(*u*)	,,	,, ,,	,,	Equatorial	125	10 6 29·2	F. B.
(*v*)	Nov. 17	Disapp. B.A.C. 8365	,,	Heliometer	45	10 39 42·5	W.
(*w*)	,,	,, ,,	,,	Equatorial	160	10 39 43·1	R.
(*x*)	,,	,, ,,	,,	Dollond	45	10 39 43·4	F. B.
(*y*)	30	Disapp. *Uranus*	Bright	Equatorial	125	16 58 42·2	F. B.
(*z*)	,,	Reapp. *Uranus*	Dark	Heliometer	110	18 8 4·2	W.
(z_1)	,,	,, ,	,,	Equatorial	125	18 8 6·4	F. B.

Remarks.

(*a*) Image of star faint and diffused at times. Not a satisfactory observation.

For observations of occultations of Struve's faint stars during the Total Eclipse of Moon on 1884, Oct. 4, *vide Monthly Notices*, ol. xlv. No. 1.

(*b*), (*g*), (*n*), (*v*) Instantaneous.

(*c*) Very good image, but did not disappear instantaneously. Observation good.

(*d*), (*f*), (*h*), (*t*), (*u*) Good.

(*e*), (*k*), (*o*), (*p*), (*w*) Good. Instantaneous.

(*i*) Magnitude = $7\frac{1}{2}$, not 6, as in *N.A.* Faint and diffused.

(*j*) Instantaneous. This star is much brighter than (*i*).

(*l*), (*r*) Star was diffused, but observation fairly good.

Remarks (continued).

(m) Very good. (q) Bad image, hazy. Moon low down. (s) Diffused. Sky hazy. (x) Star diffused.
(y) Definition of Moon good; planet diffused; disappeared quickly. Probable error, 1ᵐ·5.
(z) Good definition; may be a little late, perhaps 0ᵐ·5.
(z_1) May be 1ˢ or 2ˢ late, as I was not looking at the exact point of reappearance on the invisible limb of the Moon. The time has been diminished 30ˢ on the assumption that the wrong end of the chronometer's second-hand was taken.

In converting Oxford Mean Solar Times into Greenwich Mean Solar Times, the following Longitude has been used: 5ᵐ 2ˢ·6 *W.*

Eclipses of the IVth Satellite of Jupiter.

Ref.	Day of Obs. 1885.	Satellite.	Phenomenon.	Instrument.	Power used.	G.M.T. of Observation. h m s	G.M.T. of *N.A.* h m s	Observer.
(α)	Feb. 2	IV.	Ecl. Dis. Last seen	Equatorial	125	10 9 16	10 8 28	R.
(β)	19	,,	Ecl. Re. First suspected	Heliometer	200	8 41 42	8 41 52	W.
	,,	,,	Ecl. Re. Confirmed	,,	,,	8 43 42		
(γ)	,,	,,	Ecl. Re. First seen	Equatorial	125	8 43 40	8 41 52	F. B.
(δ)	Apr. 27	,,	,, ,,	Heliometer	160	8 34 51	8 35 43	R.
(ϵ)	,,	,,	Ecl. Re. Suspected	Equatorial	125	8 35 6	8 35 43	F. B.
	,,	,,	Ecl. Re. Verified	,,		8 35 36		

Remarks.

(α) Satellite diminished very slowly in brightness.
(β) Reappeared, almost touching limb of *Jupiter*. Markings very distinct at times. Rather hazy. (γ) Very fair observation.
(δ) Observation good, but images slightly diffused. (ϵ) Definition bad at times, but very fair observation.

Observers: W. = Mr. Wickham; R. = Mr. Robinson; F. B. = Mr. Bellamy.
Apertures: Heliometer, 7·5-inch. Equatorial, 7-inch. Dollond, 3·8-inch. Marlborough, 3·3-inch.

Observations of Eclipses, Occultations, and Transits of Jupiter's Satellites, made with the 8-inch Cooke Equatorial at the Adelaide Observatory, South Australia: Longitude, 9h. 14m. 20s·3 E.; Latitude, 34° 56′ 33″·8 S.

(*Communicated by Mr. Todd.*)

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N. A.*	Power used.
					h m s	h m s	h m s	h m s	
1	1885, Jan. 7.	C.	I. Tr. E.	Int. contact	11 5 6·7	1 50 46·4			200
2				Abt. bisected	11 7 13·7	1 52 53·4			,,
3				Ext. contact	11 10 12·5	1 55 52·2			,,
4	Jan. 15.	C.	I. Oc. R.	First seen	10 6 54·1	0 52 33·8			120
5				Ext. contact	10 10 46·3	0 56 26·0			,,
6	Feb. 16.	C.	II. Sh. E.	Int. contact	10 28 17·0	1 13 56·7			200
7				Abt. bisected	10 29 22·2	1 15 1·9			,,
8				Limb complete	10 30 47·7	1 16 27·4			,,
9	Feb. 16.	C.	II. Tr. E.	Int. contact	10 33 45·9	1 19 25·6			,,
10				Abt. bisected	10 35 18·4	1 20 58·1			,,
11				Ext. contact	10 37 35·7	1 23 15·4			,,
12	Feb. 21.	C.	I. Oc. D.	Ext. contact	10 53 42·8	1 39 22·5			,,
13				Abt. bisected	10 55 49·8	1 41 29·5			,,
14				Last seen	10 57 28·0	1 43 7·7			,,
15	Feb. 21.	C.	I. Ec. R.	First seen	13 15 27·6	4 1 7·3	4 0 59	−0 8	150±
16				Full blaze	13 17 27·6	4 3 7·3			,,

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac*.	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
17	1885, Feb. 22.	C.	I. Tr. I.	Ext. contact	8 9 49·7	22 55 29·4			150 ±
18				Abt. bisected	8 11 23·6	22 57 3·3			,,
19				Int. contact	8 14 36·8	23 0 16·5			,,
20	Feb. 22.	C.	I. Sh. I.	Limb indented	8 17 38·8	23 3 18·5			,,
21				Limb complete	8 20 35·5	23 6 15·2			,,
22	Feb. 22.	C.	I. Tr. E.	Int. contact	10 27 26·4	1 13 6·1			250 ±
23				Abt. bisected	10 29 54·3	1 15 34·0			,,
24				Ext. contact	10 33 6·9	1 18 46·6			,,
25	Feb. 22.	C.	I. Sh. E.	Int. contact	10 33 31·6	1 19 11·3			,,
26				Limb complete	10 35 47·7	1 21 27·4			,,
27	Feb. 23.	C.	II. Tr. I.	Ext. contact	9 55 30·9	0 41 10·6			150 ±
28				Abt. bisected	9 57 57·9	0 43 37·6			,,
29				Int. contact	10 2 30·9	0 48 10·6			,,
30	Feb. 23.	C.	II. Tr. E.	Int. contact	12 47 59·6	3 33 39·3			,,
31				Abt. bisected	12 50 54·6	3 36 34·3			,,
32				Ext. contact	12 54 2·6	3 39 42·3			,,
33	Feb. 23.	C.	II. Sh. E.	Int. contact	13 2 20·6	3 48 0·3			,,
34				Still indented	13 4 17·6	3 49 57·3			,,
35				Ext. contact	13 4 57·6	3 50 37·3			,,
36	Feb. 25.	C.	II. Ec. R.	First seen	8 5 29·3	22 51 9·0	22 51 26	+0 17	,,

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
37				Quite distinct	8 5 56·4	22 51 36·1			150±
38				Full blaze	8 8 44·8	22 54 24·5			,,
39	1885, Feb. 28.	C.	I. Oc. D.	Ext. contact	12 36 6·7	3 21 46·4			,,
40				Abt. bisected	12 38 6·7	3 23 46·4			,,
41				Last seen	12 40 35·7	3 26 15·4			,,
42	Feb. 28.	C.	I. Ec. R.	First seen	15 9 18·5	5 54 58·2	5 54 57	−0 1	,,
43				Quite distinct	15 9 32·3	5 55 12·0			,,
44				Full blaze	15 13 22·3	5 59 2·0			,,
45	March 1.	C.	I. Tr. I.	Ext. contact	9 51 42·1	0 37 21·8			,,
46				Int. contact	9 56 54·7	0 42 34·4			,,
47	March 2.	C.	I. Ec. R.	First seen	9 38 5·2	0 23 44·9	0 23 27	−0 18	,,
48				Quite distinct	9 38 18·1	0 23 57·8			,,
49				Full blaze	9 42 18·1	0 27 57·8			,,
50	March 2.	C.	II. Tr. I.	Ext. contact	12 9 37·7	2 55 17·4			,,
51				Abt. bisected	12 12 7·7	2 57 47·4			,,
52				Int. contact	12 15 43·7	3 1 23·4			,,
53	March 2.	C.	II. Sh. I.						
54	March 4.	C.	II. Ec. R.	First seen	10 41 45·2	1 27 24·9	1 27 51	+0 26	200
55				Quite distinct	10 41 52·5	1 27 32·2			,,
56				Full blaze	10 45 47·5	1 31 27·2			,,

	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
57	1885, March 8.	C.	I. Tr. I.	Ext. contact	11 40 0·0	2 25 39·7			200
58				Abt. bisected	11 42 6·0	2 27 45·7			,,
59				Int. contact.	11 43 56·0	2 29 35·7			,,
60	March 8.	C.	IV. Ec. R.	First seen	11 53 45·0	2 39 24·7	2 39 47	+0 22	,,
61				Quite distinct	11 54 0·0	2 39 39·7			,,
62				Full blaze	11 58 40·0	2 44 19·7			,,
63	March 8.	C.	I. Sh. I.	First seen	12 6 21·0	2 52 0·7			,,
64				Int. contact	12 8 16·0	2 53 55·7			,,
65	March 8.	C.	I. Tr. E.	Ext. contact	14 0 33·8	4 46 13·5			,,
66	March 8.	C.	I. Sh. E.	Int. contact	14 21 6·7	5 6 46·4			,,
67				Still indented	14 24 12·7	5 9 52·4			,,
68				Limb complete	14 24 25·7	5 10 5·4			,,
69	March 9.	S.	I. Oc. D.	Ext. contact	8 47 32·1	23 33 11·8			,,
70				Abt. bisected	8 49 47·1	23 35 26·8			,,
71				Limb complete	8 51 7·1	23 36 46·8			,,
72	March 9.	S.	I. Ec. R.	First seen	11 31 47·7	2 17 27·4	2 17 36	+0 9	,,
73				Full blaze	11 35 56·7	21 21 36·4			,,
74	March 9.	S.	II. Tr. I.	Ext. contact	14 23 56·3	5 9 36·0			,,
75				Abt. bisected	14 26 26·3	5 12 6·0			,,
76				Int. contact	14 29 36·3	5 15 16·0			,,

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
77	1885, March 10.	S.	III. Ec. R.	First seen	8 0 49·1	22 46 28·8	22 46 52	+0 23	200
78				Quite distinct	8 1 34·1	22 47 13·8			,,
79				Full blaze	8 6 34·1	22 52 13·8			,,
80	March 10.	S.	I. Tr. E.	Int. contact	8 21 29·1	23 7 8·8			,,
81				Ext. contact	8 26 9·1	23 11 48 8			,,
82	March 10.	S.	I. Sh. E.	Int. contact	8 50 19·0	23 35 58·7			,,
83				Limb complete	8 52 54·0	23 38 33·7			,,
84	March 15.	S.	I. Tr. I.	Ext. contact	13 22 39·3	4 8 19·0			,,
85				Abt. bisected	13 25 35·3	4 11 15·0			,,
86				Int. contact	13 28 50·3	4 14 30 0			,,
87	March 15.	S.	I. Sh. I.	Int. contact	14 3 0·3	4 48 40·0			,,
88	March 16.	S.	IV. Tr. I.	Ext. contact	9 2 57·0	23 48 36·7			,,
89				Abt. bisected	9 9 52·0	23 55 31·7			,,
90				Int. contact	9 16 47·0	0 2 26·7			,,
91	March 16.	S.	I. Oc. D.	Ext. contact	10 30 46·7	1 16 26·4			120
92				Limb complete	10 35 36·7	1 21 16·4			,,
93	March 16.	S.	I. Ec. R.	First seen	13 25 59·3	4 11 39·0	4 11 54	+0 15	,,
94				Full blaze	13 30 26·3	4 16 6·0			,,
95	March 16.	S.	IV. Tr. E.	Ext. contact	13 53 41·3	4 39 21·0			

Ref No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac*.	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
96	1885, March 17.	S.	I. Tr. I.	Int. contact	7 57 4·8	22 42 44·5			200
97	March 17.	S.	I. Sh. I.	First seen	8 29 14·8	23 14 54·5			"
98				Int. contact	8 31 39·8	23 17 19·5			"
99	March 17.	S.	I. Sh. E.	Int. contact	10 44 24·5	1 30 4·2			"
100				Still indented	10 47 9·5	1 32 49·2			"
101				Limb complete	10 47 34·5	1 33 14·2			"
102	March 17.	S.	III. Ec. R.	First seen	11 59 55·4	2 45 35·1	2 45 12	− 0 23	120
103				Full blaze	12 5 44·4	2 51 24·1			"
104	March 18.	C.	I. Ec. R.	First seen	7 54 45·1	22 40 24·8	22 40 30	+0 5	200
105				Quite distinct	7 54 56·9	22 40 36·6			"
106				Full blaze	7 58 51·9	22 44 31·6			"
107	March 18.	S.	II. Oc. D.	Ext. contact	11 39 41·3	2 25 21·0			"
108				Abt. bisected	11 43 49·3	2 29 29·0			"
109				Still visible	11 45 11·3	2 30 51·0			"
110				Disappearance	11 45 29·3	2 31 9·0			"
111	March 20.	S.	II. Tr. E.	Ext. contact	9 48 36·9	0 34 16·6			"
112	March 23.	S.	I. Oc. D.	Ext. contact	12 17 7·1	3 2 46·8			"
113				Abt. bisected	12 19 59·1	3 5 38·8			"
114				Still visible	12 21 32·1	3 7 11·8			"

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
115				Disappearance	12 21 42·1	3 7 21·8			200
116	1885, March 24.	S.	I. Tr. I.	Abt. bisected	9 38 54·8	0 24 34·5			,,
117				Int. contact	9 42 4·8	0 27 44·5			,,
118	March 24.	S.	I. Sh. I.	First seen	10 24 14·7	1 9 54·4			120
119				Int. contact	10 26 54·7	1 12 34·4			,,
120	March 27.	S.	II. Tr. I.	Ext. contact	8 10 15·9	22 55 55·6			200
121				Abt. bisected	8 12 15·9	22 57 55·6			,,
122				Int. contact	8 14 30·9	23 0 10·6			,,
123	March 27.	S.	II. Sh. I.	First seen	9 48 40·7	0 34 20·4			,,
124				Int. contact	9 51 5·7	0 36 45·4			,,
125	March 27.	S.	II. Tr. E.	Int. contact	11 1 15·5	1 46 55·2			,,
126				Abt. bisected	11 3 10·5	1 48 50·2			,,
127				Ext. contact	11 5 40·5	1 51 20·2			,,
128	April 1.	S.	I. Oc. D.	Ext. contact	8 31 35·8	23 17 15·5			,,
129				Still visible	8 35 25·8	23 21 5·5			,,
130				Disappearance	8 35 33·8	23 21 13·5			,,
131	April 1.	S.	I. Ee. R.	First seen	11 43 39·5	2 29 19·2	2 29 35	+0 16	,,
132				Quite distinct	11 43 45·5	2 29 25·2			,,
133				Full blaze	11 46 20·5	2 32 0·2			,,

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac*.	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
134	1885, April 2.	S.	I. Tr. E.	Int. contact	8 9 18·2	22 54 57·9			200
135				Ext. contact	8 12 43·2	22 58 22·9			,,
136	April 2.	S.	IV. Sh. I.	Int. contact	8 49 33·2	23 35 12·9			,,
137	April 8.	C.	I. Oc. D.	Ext. contact	10 19 38·0	1 5 17·7			,,
138				Abt. bisected	10 21 26·0	1 7 5·7			,,
139				Still visible	10 23 32·0	1 9 11·7			,,
140				Disappearance	10 23 42·0	1 9 21·7			,,
141	April 9.	C.	I. Tr. I.	Ext. contact	7 40 39·6	22 26 19·3			300
142				Abt. bisected	7 42 58·6	22 28 38·3			,,
143				Int. contact	7 45 13·6	22 30 53·3			,,
144	April 9.	C.	I. Sh. I.	First seen	8 42 38·0	23 28 17·7			200
145				Int. contact	8 45 29·5	23 31 9·2			,,
146	April 9.	C.	I. Tr. E.	Int. contact	9 57 33·3	0 43 13·0			300
147				Abt. bisected	9 59 23·3	0 45 3·0			,,
148				Ext. contact	10 1 37·3	0 47 17·0			,,
149	April 9.	C.	I. Sh. E.	Int. contact	10 57 33·2	1 43 12·9			200
150				Limb complete	11 0 25·2	1 46 4·9			,,
151	April 10.	C.	I. Ec. R.	First seen	8 7 12·7	22 52 52·4	22 52 57	+0 5	,,
152				Quite distinct	8 7 20·9	22 53 0·6			,,

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
153				Full blaze	8 10 50·9	22 56 30·6			200
154	1885, April 10.	C.	IV. Oc. D.	Ext. contact	9 23 30·8	0 9 10·5			,,
155				Still visible	9 31 10 8	0 16 50·5			,,
156				Disappearance	9 31 26·8	0 17 6·5			,,
157	April 17.	C.	I. Oc. D.	Ext. contact	6 37 24·0	21 23 3·7			300
158				Abt. bisected	6 39 11·0	21 24 50·7			,,
159				Int. contact	6 40 50·0	21 26 29·7			,,
160	April 27.	C.	IV. Oc. R.	Ext. contact	6 36 35·7	21 22 15·4			200
161	April 28.	C.	II. Tr. I.	Ext. contact	7 4 3·1	21 49 42·8			,,
162				Abt. bisected	7 6 27·1	21 52 6·8			,,
163				Int. contact	7 8 40·1	21 54 19·8			,,
164	April 28.	C.	II. Sh. I.	Int. contact	9 32 12·8	0 17 52·5			,,
165	April 28.	C.	II. Tr. E.	Abt. bisected	9 58 32·8	0 44 12 5			,,
166				Ext. contact	10 0 25·8	0 46 5·5			,,
167	April 29.	S.	III. Oc. R.	First seen	7 1 35·8	21 47 15·5			,,
168				Ext. contact	7 3 0·8	21 48 40·5			,,
169	April 29.	S.	III. Ec. D.	Very faint	8 30 30 7	23 16 10·4			,,
170				Disappearance	8 30 52·7	23 16 32·4	23 12 41	−3 51	,,
171	April 29.	C.	III. Ec. R.	First seen	11 53 44·2	2 39 23·9	2 38 10	−1 14	120

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
172				Quite distinct	11 53 57·4	2 39 37·1			120
173				Full blaze	12 1 10·4	2 46 50·1			,,
174	1885, April 30.	C.	II. Ec. R.	First seen	7 30 51·6	22 16 31·3	22 17 17	+0 46	200
175				Quite distinct	7 31 5·8	22 16 45·5			,,
176				Full blaze	7 35 7·8	22 20 47·5			,,
177	May 2.	C.	I. Tr. I.	Ext. contact	7 41 26·1	22 27 5·8			300
178				Abt. bisected	7 44 9·1	22 29 48·8			,,
179				Int. contact	7 46 9·1	22 31 48·8			,,
180	May 10.	C.	I. Oc. D.	Ext. contact	6 42 1·5	21 27 41·2			200
181				Abt. bisected	6 43 44·5	21 29 24·2			,,
182				Last seen	6 45 22·5	21 31 2·2			,,
183	May 10.	C.	I. Ec. R.	First seen	10 15 57·2	1 1 36·9	1 1 33	−0 4	,,
184				Quite distinct	10 16 6·2	1 1 45 9			,,
185				Full blaze	10 19 44·2	1 5 23·9			,,
186	May 22.	S.	IV. Tr. E.	Ext. contact	7 32 21·3	22 18 1·0			,,
187	May 25.	S.	I. Tr. I.	Ext. contact	7 52 21 9	22 38 1·6			,,
188				Abt. bisected	7 54 41·9	22 40 21·6			,,
189				Int. contact	7 58 21·9	22 44 1·6			,,
190	May 27.	S.	I. Sh. E.	Int. contact	5 50 16·9	20 35 56·6			,,

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
191				Limb complete	5 53 16·9	20 38 56·6			200
192	1885, May 30.	S.	II. Tr. I.	Ext. contact	6 40 37·4	21 26 17·1			,,
193				Abt. bisected	6 42 47·4	21 28 27·1			,,
194				Int. contact	6 46 52·4	21 32 32·1			,,
195	June 1.	S.	II. Ec. R.	First seen	7 10 32·8	21 56 12·5	21 56 49	+0 37	,,
196				Quite distinct	7 10 37·8	21 56 17·5			,,
197				Full blaze	7 13 32·8	21 59 12·5			,,
198	June 9.	C.	I. Oc. D.	Ext. contact	8 53 54·5	23 39 34·2			,,
199				Abt. bisected	8 55 41·5	23 41 21·2			,,
200				Last seen	8 57 4·5	23 42 44·2			,,
201	June 10.	S.	I. Tr. I.	Ext. contact	6 15 33·5	21 1 13·2			,,
202				Abt. bisected	6 17 28·5	21 3 8·2			,,
203				Int. contact	6 20 18·5	21 5 58·2			,,
204	June 10.	S.	I. Tr. E.	Ext. contact	8 37 33·5	23 23 13·2			,,
205	June 11.	C.	I. Ec. R.	First seen	6 54 8·4	21 39 48·1	21 39 37	−0 11	,,
206				Quite distinct	6 54 12·9	21 39 52·6			,,
207				Full blaze	6 57 40·9	21 43 20·6			,,
208	June 11.	C.	III. Oc. R.	First seen	7 3 23·9	21 49 3·6			300
209				Ext. contact	7 8 20·9	21 54 0·6			,,

Ref. No.	Date.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Time by *Nautical Almanac.*	Apparent Error of *N.A.*	Power used.
					h m s	h m s	h m s	h m s	
210	1885, June 11.	C.	III. Ec. D.	Very faint	8 27 30·9	23 13 10·6			200
211				Last seen	8 27 42·9	23 13 22·6	23 10 18	−3 5	"
212	June 17.	S.	I. Tr. I.	Ext. contact	8 12 48·9	22 58 28·6			120
213				Int. contact	8 18 8·9	23 3 48·6			"
214	July 6.	C.	III. Tr. I.	Ext. contact	6 12 43·5	20 58 23·2			200
215				Abt. bisected	6 16 26·5	21 2 6·2			"
216				Int. contact	6 22 31·5	21 8 11·2			"
217	July 12.	C.	I. Tr. E.	Int. contact	5 25 37·8	20 11 17·5			"
218				Abt. bisected	5 27 37·8	20 13 17·5			"
219				Ext. contact	5 29 47·8	20 15 27·5			"

Observers: C. = Mr. Cooke. S. = Mr. Sells.

Drawings of Jupiter and Saturn.

The Society has been presented by Mr. C. Todd with a series of 28 drawings of *Jupiter*, made at Adelaide with the 8-inch refractor between 1885, April 27, and 1886, February 9; and by Mr. K. F. Tarrant, with four drawings of *Jupiter* on 1885, February 15, March 15, 21, 29, and one of *Saturn*, made with a reflector of 10 inches aperture. These drawings have been placed in the Library.

MONTHLY NOTICES

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William Edgar Butcher, H.M.S. *Superb*, Mediterranean Squadron;

J. D. McClure, B.A., 71 Jesus Lane, Cambridge; and

Charles Ridley Smith, 44 Lower Belgrave Street, Eaton Square, S.W.;

were balloted for and duly elected Fellows of the Society.

Comparisons of certain Southern Star Catalogues.

By A. M. W. Downing, M.A.

Finding that I had amongst my papers complete comparisons (*i.e.* giving $\Delta\alpha_*$, $\Delta\alpha_\nu$, $\Delta\delta_*$, and $\Delta\delta_\nu$) of the following Star Catalogues:—

I. The Cape Catalogues for 1840 and 1850,
II. The Cape Catalogues for 1840 and 1860,
III. The Cape Catalogues for 1850 and 1880,
IV. The Cape Catalogue for 1860 and the Melbourne Catalogue for 1870,
V. The Melbourne Catalogue for 1870 and the Cape Catalogue for 1880,

it occurred to me that, as only some of these comparisons had been published, from time to time, as opportunity offered, it would be desirable to publish the remainder, in order to avoid the risk of loss which a further postponement of publication might entail. I accordingly now take the liberty of offering them to the Society, not because they are of any special interest at the present time, but with the hope that they may be of use

to astronomers engaged on researches demanding a knowledge of the systematic discordances of the Star Catalogues above-mentioned.

I. *The Cape Catalogues for* 1840 *and* 1850.

The comparison in Right Ascension when the stars are arranged in order of N.P.D. is given in *Monthly Notices*, vol. xlv. pp. 299, 300. To find the discordances in R.A. depending on R.A., the differences have been arranged in order of R.A., and combined in groups extending each over one hour of R.A., and thus the following mean differences found:—

R.A.	Mean $\Delta\alpha$ 1840–1850.	Number of Stars.	R.A.	Mean $\Delta\alpha$ 1840–1850.	Number of Stars.
h h	s		h h	s	
0–1	−0·160	45	12–13	−0·029	37
1–2	−0·127	46	13–14	−0·004	50
2–3	−0·154	52	14–15	−0·009	36
3–4	−0·087	49	15–16	−0·009	64
4–5	−0·054	50	16–17	−0.060	65
5–6	−0·041	40	17–18	−0·010	62
6–7	−0·070	73	18–19	+0·010	52
7–8	−0·040	71	19–20	−0·062	34
8–9	+0·027	49	20–21	+0·017	29
9–10	+0·066	40	21–22	−0·023	32
10–11	+0·062	18	22–23	−0·040	31
11–12	+0·058	38	23–24	−0·054	33

By drawing a curve representing these mean differences in the usual way, and reading off from it for the beginning of each hour (noting that the mean of the groups of differences in R.A. arranged in order of N.P.D. given in the paper referred to above is $-0^s{\cdot}037$, and applying this with opposite sign to each $\Delta\alpha$) we have the final table of differences in R.A. depending on R.A.

R.A.	$\Delta\alpha_a$ (1840–1850).	R.A.	$\Delta\alpha_a$ (1840–1850).
h	s	h	s
0·0	−0·066	12·0	+0·054
1·0	−0·096	13·0	+0·031
2·0	−0·100	14·0	+0·025
3·0	−0·078	15·0	+0·018
4·0	−0·039	16·0	+0·009
5·0	−0·021	17·0	+0·008
6·0	−0·013	18·0	+0·019
7·0	−0·002	19·0	+0·021

R.A.	$\Delta\alpha_s$ (1840–1850).	R.A.	$\Delta\alpha_s$ (1840–1850).
h	s	h	s
8·0	+0·035	20·0	+0·023
9·0	+0·077	21·0	+0·021
10·0	+0·097	22·0	+0·012
11·0	+0·087	23·0	−0·024

For the N.P.D.s of these Catalogues, the differences have been formed by bringing up the places of the stars which are common to the Catalogues from the 1840 Catalogue, using the proper motions of the 1880 Catalogue, to 1850 and taking the differences, in the sense 1840–1850, between these and the N.P.D.s given in the 1850 Catalogue. These differences have then been arranged in order of N.P.D., and combined, generally, in groups extending each over 5°, and thus the following mean differences formed :—

N.P.D.	Mean $\Delta\delta$ 1840–1850.	Number of Stars.	N.P.D.	Mean $\Delta\delta$ 1840–1850.	Number of Stars.
° ′	″		° ′	″	
92·41	+0·63	13	137·54	−0·29	128
98·2	+0·63	15	141·55	−0·45	112
103·14	−0·22	25	147·43	−0·71	125
107·14	−0·45	60	152·26	−1·05	85
112·34	+0·02	79	157·39	−1·02	86
117·5	0·00	119	162·38	+0·27	33
122·7	−0·05	132	167·19	+0·19	28
127·24	−0·29	138	173·22	−0·04	12
132·37	−0·65	155			

The total number of stars used in this comparison is 1345. By drawing a reduction curve, in the usual way, and reading off from it, we have :—

N.P.D.	$\Delta\delta_s$ (1840–1850).	N.P.D.	$\Delta\delta_s$ (1840–1850.)
°	″	°	″
95	+0·54	135	−0·45
100	+0·25	140	−0·44
105	−0·19	145	−0·62
110	−0·20	150	−0·84
115	−0·04	155	−0·85
120	−0·04	160	−0·44
125	−0·19	165	+0·08
130	−0·37	170	+0·10

The differences of N.P.D. of these Catalogues, when arranged in order of R.A. and combined in groups extending each over one hour of R.A., are:—

R.A.	Mean $\Delta\delta$ 1840–1850.	Number of Stars.	R.A.	Mean $\Delta\delta$ 1840–1850.	Number of Stars.
h h	"		h h	"	
0–1	−0·29	28	12–13	−0·60	62
1–2	−0·41	40	13–14	−0·37	62
2–3	−0·46	40	14–15	−0·53	74
3–4	−0·38	69	15–16	−0·94	80
4–5	−0·17	68	16–17	−0·81	69
5–6	−0·07	83	17–18	−0·82	61
6–7	−0·04	99	18–19	−0·27	35
7–8	+0·13	98	19–20	−1·08	16
8–9	−0·28	91	20–21	−0·83	14
9–10	−0·35	64	21–22	−0·20	17
10–11	−0·52	73	22–23	−0·11	17
11–12	−0·53	67	23–24	+0·47	18

The reading of the reduction curve for the beginning of each hour of R.A. has been taken, and +0″·37 applied to each reading to correct for the mean discordance depending on N.P.D. We thus find the following table of discordances depending on R.A.:—

R.A.	$\Delta\delta_a$ (1840–1850).	R.A.	$\Delta\delta_a$ (1840–1850).
h	"	h	"
0·0	+0·37	12·0	−0·18
1·0	+0·13	13·0	−0·13
2·0	−0·07	14·0	−0·15
3·0	−0·05	15·0	−0·33
4·0	+0·09	16·0	−0·46
5·0	+0·24	17·0	−0·42
6·0	+0·33	18·0	−0·26
7·0	+0·36	19·0	−0·26
8·0	+0·28	20·0	−0·26
9·0	+0·08	21·0	−0·17
10·0	−0·07	22·0	+0·20
11·0	−0·15	23·0	+0·42

II. *The Cape Catalogues for* 1840 *and* 1860.

The comparison in N.P.D., when the stars are arranged in order of N.P.D., is given, for these two Catalogues, in *Monthly Notices*, vol. xli. pp. 150, 151.

The differences of R.A., deduced as for the preceding comparisons, arranged in order of N.P.D., and combined in groups extending each over 5° of N.P.D., give the following table :—

N.P.D.	Mean $\Delta\alpha$ 1840-1860.	Number of Stars.	N.P.D.	Mean $\Delta\alpha$ 1840-1860.	Number of Stars.
° ′	s		° ′	s	
39·0	−0·110	3	112·54	−0·016	18
55·4	−0·063	7	117·23	+0·006	48
62·5	+0·001	13	122·34	+0·036	49
68·25	−0·034	22	127·20	+0·024	40
71·56	+0·001	13	132·44	+0·018	56
77·19	−0·004	16	137·31	+0 052	33
82·32	+0·018	23	142·37	−0·009	31
87·9	+0·014	14	147·21	+0·005	32
91·47	+0·039	9	152·29	−0·013	29
98·5	−0·019	14	157·18	+0·015	30
102·30	−0·019	12	165·54	−0·070	20
107·36	+0·017	21	174·14	−0·030	20

The total number of stars used in this comparison is 573.

The reduction curve, constructed in the usual way, gives the following readings :—

N.P.D.	$\Delta\alpha_\delta$ (1840–1860).	N.P.D.	$\Delta\alpha_\delta$ (1840–1860).
°	s	°	s
65	−0·020	120	+0·017
70	−0·012	125	+0·026
75	−0·003	130	+0·027
80	+0·008	135	+0·028
85	+0·019	140	+0·020
90	+0·021	145	+0·002
95	+0·005	150	−0·003
100	−0·008	155	−0·008
105	−0·006	160	−0·023
110	−0·001	165	−0·035
115	+0·001	174·4	−0·030

The differences of R.A., arranged in order of R.A., and combined in groups extending each over one hour of R.A., give the following table :—

R.A.	Mean $\Delta\alpha$ 1840–1860.	Number of Stars.	R.A.	Mean $\Delta\alpha$ 1840–1860.	Number of Stars.
h h	s		h h	s	
0–1	−0·013	19	12–13	+0·039	23
1–2	+0·016	28	13–14	+0·093	19
2–3	−0·022	20	14–15	+0·059	20
3–4	−0·006	22	15–16	+0·007	37
4–5	−0·001	29	16–17	−0·008	25
5–6	−0·020	28	17–18	−0·053	35
6–7	+0·048	23	18–19	−0·017	33
7–8	+0·019	26	19–20	−0·044	20
8–9	+0·016	22	20–21	−0·048	21
9–10	+0·060	22	21–22	−0·014	18
10–11	+0·048	20	22–23	−0·025	23
11–12	+0·024	22	23–24	+0·028	18

Reading off from the reduction curve for the beginning of each hour of R.A., and applying $-0^{s}\cdot005$ to correct for the mean discordance in R.A. depending on N.P.D., we have :—

R.A.	$\Delta\alpha_s$ (1840–1860).	R.A.	$\Delta\alpha_s$ (1840–1860).
h	s	h	s
0·0	0·000	12·0	+0·036
1·0	−0·004	13·0	+0·053
2·0	−0·010	14·0	+0·055
3·0	−0·014	15·0	+0·031
4·0	−0·014	16·0	−0·005
5·0	−0·008	17·0	−0·030
6·0	+0·008	18·0	−0·038
7·0	+0·021	19·0	−0·042
8·0	+0·022	20·0	−0·044
9·0	+0·032	21·0	−0·037
10·0	+0·041	22·0	−0·023
11·0	+0·035	23·0	−0·006

The differences of the N.P.D.s of these two Catalogues when the stars are arranged in order of R.A. and combined in groups extending each over one hour of R.A. are :—

R.A.	Mean Δδ 1840–1860.	Number of Stars.	R.A.	Mean Δδ 1840–1860.	Number of Stars.
h h	"		h h	"	
0–1	−0·25	13	12–13	+0·12	13
1–2	+0·10	20	13–14	+0·35	17
2–3	−0·05	11	14–15	+0·46	13
3–4	−0·19	16	15–16	+0·08	24
4–5	+0·03	23	16–17	−0·23	17
5–6	−0·01	17	17–18	−0·11	21
6–7	+0·08	20	18–19	+0·04	16
7–8	+0·26	19	19–20	−0·13	12
8–9	−0·31	18	20–21	+0·02	9
9–10	−0·05	20	21–22	−0·04	14
10–11	−0·08	24	22–23	+0·10	16
11–12	+0·32	15	23–24	+0·06	13

Applying a correction of −0″·02 for mean discordance in N.P.D. depending upon N.P.D., the reduction curve gives:—

R.A.	$\Delta\delta_c$ (1840–1860).	R.A.	$\Delta\delta_c$ (1840–1860)
h	"	h	"
0·0	−0·07	12·0	+0·20
1·0	−0·07	13·0	+0·28
2·0	−0·05	14·0	+0·32
3·0	−0·10	15·0	−0·21
4·0	−0·10	16·0	−0·05
5·0	−0·03	17·0	−0·14
6·0	+0·06	18·0	−0·10
7·0	+0·07	19·0	−0·07
8·0	−0·05	20·0	−0·07
9·0	−0·15	21·0	−0·04
10·0	−0·10	22·0	+0·01
11·0	+0·09	23·0	0·00

III.—*The Cape Catalogues for* 1850 *and* 1880.

The comparison in R.A. of these two Catalogues, when the stars are arranged in order of N.P.D., is given in *Monthly Notices*, vol. xlv. pp. 298, 299. Using the materials on pp. viii. and ix. of the Introduction to the Cape Catalogue for 1850, where the stars are combined in order of R.A. in groups extending each over 4 hours of R.A., we have the following mean differences:—

R.A.		Mean $\Delta\alpha$ 1850–1880.	Number of Stars.	R.A.		Mean $\Delta\alpha$ 1850–1880.	Number of Stars.
h	m	s		h	m	s	
2	4	+0·049	541	14	19	+0·164	425
6	12	+0·119	673	17	50	+0·078	718
9	40	+0·110	535	21	59	+0·028	476

The correction for mean discordance in R.A. depending on N.P.D. is $-0^{s}\cdot090$, and applying this the reduction curve gives:

R.A.	$\Delta\alpha_c$ (1850–1880).	R.A.	$\Delta\alpha_c$ (1850–1880).
h	s	h	s
0·0	−0·055	12·0	+0·046
1·0	−0·050	13·0	+0·057
2·0	−0·042	14·0	+0·072
3·0	−0·021	15·0	+0·058
4·0	−0·002	16·0	+0·035
5·0	+0·014	17·0	+0·013
6·0	+0·028	18·0	−0·004
7·0	+0·027	19·0	−0·023
8·0	+0·025	20·0	−0·040
9·0	+0·022	21·0	−0·056
10·0	+0·022	22·0	−0·063
11·0	+0·033	23·0	−0·059

Again, making use of the materials given in the Introduction to the 1850 Catalogue, and combining the stars arranged in order of N.P.D. in groups of 6°, we have:—

N.P.D.		Mean $\Delta\delta$ 1850–1880.	Number of Stars.	N.P.D.		Mean $\Delta\delta$ 1850–1880.	Number of Stars
°	′	″		°	′	″	
92	55	−0·59	136	141	0	−0·59	328
98	51	−0·47	145	147	1	−0·80	338
104	58	−0·35	117	151	42	−0·35	292
112	5	−0·60	156	158	43	−0·38	193
116	51	−0·50	533	164	46	−0·97	73
122	37	−0·28	404	170	14	−0·65	59
129	4	−0·12	376	176	7	−0·07	5
134	55	−0·33	380				

The total number of stars used in this comparison is 3535. Reading off the differences of N.P.D. from the curve, drawn in the usual manner, gives the following table:—

N.P.D.	$\Delta\delta_\theta$ (1850–1880).	N.P.D.	$\Delta\delta_\theta$ (1850–1880).
°	″	°	″
95	−0·54	135	−0·33
100	−0·43	140	−0·54
105	−0·35	145	−0·69
110	−0·54	150	−0·55
115	−0·56	155	−0·38
120	−0·39	160	−0·44
125	−0·20	165	−0·57
130	−0·13	170	−0·74

From the data on page xiv. of the Introduction to the 1850 Catalogue, where the stars are combined in groups extending each over 4 hours of R.A., the following mean differences are found :—

R.A.	Mean Δδ 1850–1880.	Number of Stars.	R.A.	Mean Δδ 1850–1880.	Number of Stars.
h m	″		h m	″	
2 4	−0·29	491	14 19	−0·57	488
6 12	−0·10	635	17 50	−0·66	750
9 40	−0·24	639	21 59	−0·83	532

Reading off from the reduction curve, and applying + 0″·45 for mean discordance in N.P.D., when the stars are arranged in order of N.P.D. we have :—

R.A.	$\Delta\delta_\alpha$ (1850–1880).	R.A.	$\Delta\delta_\alpha$ (1850–1880).
h	″	h	″
0·0	−0·12	12·0	+0·05
1·0	0·00	13·0	−0·03
2·0	+0·15	14·0	−0·10
3·0	+0·20	15·0	−0·13
4·0	+0·26	16·0	−0·16
5·0	+0·31	17·0	−0·18
6·0	+0·34	18·0	−0·22
7·0	+0·33	19·0	−0·25
8·	+0·29	20·0	−0·30
9·0	+0·25	21·0	−0·35
10·0	+0·18	22·0	−0·38
11·0	+0·12	23·0	−0·27

IV.—*The Cape Catalogue for* 1860 *and the Melbourne Catalogue for* 1870.

The R.A.s of the stars which are common to these two Catalogues, as given in the 1860 Catalogue, have been brought up to 1870, using the proper motions of the Cape Catalogue for

1880, and the differences Cape 1860 *minus* Melbourne 1870 taken. These, when arranged in order of N.P.D. and combined in groups extending, generally, over 5° of N.P.D., give the following mean differences :—

N.P.D.	Mean $\Delta\alpha$ 1860–1870.	Number of Stars.	N.P.D.	Mean $\Delta\alpha$ 1860–1870.	Number of Stars.
° ′	s		° ′	s	
48 0	−0·050	5	117 32	−0·001	21
57 13	−0·023	3	122 24	−0·003	12
62 10	+0·005	10	128 6	−0·056	22
67 56	−0·001	9	132 35	−0·010	45
72 14	−0·017	7	137 17	−0·059	31
77 19	+0·022	13	142 52	−0·081	16
82 47	+0·014	13	147 41	−0·056	23
87 20	+0·023	11	152 17	−0·044	29
91 54	−0·013	11	157 18	−0·092	34
97 52	−0·013	8	162 14	−0·026	10
102 39	−0·010	5	167 40	+0·015	15
107 22	+0·022	9	172 11	+0·078	24
112 54	−0·016	8	176 45	+0·187	12

The total number of stars used in this comparison is 406. A curve representing these differences being drawn in the usual manner, the following table is found by reading off from it :—

N.P.D.	$\Delta\alpha_\delta$ (1860–1870).	N.P.D.	$\Delta\alpha_\delta$ (1860–1870).
°	s	°	s
52	−0·038	112	−0·003
56	−0·024	116	−0·005
60	−0·011	120	−0·012
64	−0·004	124	−0·022
68	−0·003	128	−0·032
72	−0·003	132	−0·035
76	+0·006	136	−0·048
80	+0·017	140	−0·063
84	+0·018	144	−0·069
88	+0·009	148	−0·059
92	−0·004	152	−0·058
96	−0·013	156	−0·063
100	−0·010	160	−0·050
104	0·000	164	−0·021
108	+0·004	168	+0·018

The differences in R.A. of these two Catalogues being arranged in order of R.A., and combined in groups extending each over one hour of R.A., give:—

R.A.	Mean $\Delta\alpha$ 1860–1870.	Number of Stars.	R.A.	Mean $\Delta\alpha$ 1860–1870.	Number of Stars.
h h	s		h h	s	
0–1	−0·020	15	12–13	−0·021	17
1–2	−0·031	20	13–14	−0·016	16
2–3	−0·033	12	14–15	−0·008	13
3–4	−0·071	13	15–16	−0·038	20
4–5	−0·056	19	16–17	−0·002	13
5–6	−0·030	17	17–18	+0·026	22
6–7	+0·039	12	18–19	+0·019	24
7–8	+0·012	17	19–20	−0·027	19
8–9	−0·068	20	20–21	−0·056	13
9–10	−0·040	19	21–22	−0·009	17
10–11	+0·041	23	22–23	+0·002	20
11–12	+0·042	10	23–24	−0·029	15

Reading off from the reduction curve for the beginning of each hour of R.A., and applying + 0ˢ·016 to each difference to correct for the mean discordance in R.A. when the stars are arranged in order of N.P.D., we have:—

R.A.	$\Delta\alpha_a$ (1860–1870).	R.A.	$\Delta\alpha_a$ (1860–1870).
h	s	h	s
0·0	−0·007	12·0	+0·028
1·0	−0·011	13·0	+0·005
2·0	−0·017	14·0	−0·002
3·0	−0·034	15·0	−0·005
4·0	−0·041	16·0	+0·002
5·0	−0·022	17·0	+0·025
6·0	+0·015	18·0	+0·033
7·0	+0·023	19·0	+0·011
8·0	−0·004	20·0	−0·017
9·0	−0·019	21·0	−0·014
10·0	+0·016	22·0	+0·005
11·0	+0·051	23·0	+0·004

The mean differences in N.P.D., for groups extending over 5° of N.P.D. arranged in order of N.P.D., have been taken from L. de Ball's paper "Untersuchungen über die eigene Bewegung des

Sonnensystems," page 2, and a reduction curve drawn, the readings from which are as follows:—

N.P.D.	$\Delta\delta_{\delta}$(1860-1870).	N.P.D.	$\Delta\delta_{\delta}$(1860-1870).
°	″	°	″
64	−0·17	120	+0·52
68	0·00	124	+0·43
72	+0·13	128	+0·42
76	+0·18	132	+0·51
80	+0·22	136	+0·63
84	+0·23	140	+0·65
88	+0·25	144	+0·68
92	+0·28	148	+0·70
96	+0·24	152	+0·70
100	+0·22	156	+0·62
104	+0·24	160	+0·55
108	+0·32	164	+0·47
112	+0·42	168	+0·37
116	+0·52		

The total number of stars used in this comparison is 388. The differences of N.P.D. when the stars are arranged in order of R.A. have been computed directly, and having been combined in groups extending each over one hour of R.A., there results:—

R.A.	Mean Δδ 1860-1870.	Number of Stars.	R.A.	Mean Δδ 1860-1870.	Number of Stars.
h h	″		h h	″	
0–1	+0·48	16	12–13	+0·69	17
1–2	+0·64	21	13–14	−0·04	16
2–3	+1·08	12	14–15	+0·44	13
3–4	+0·64	11	15–16	+0·38	20
4–5	+0·47	19	16–17	+0·10	13
5–6	+0·41	17	17–18	+0·40	22
6–7	+0·28	12	18–19	−0·02	24
7–8	+0·42	17	19–20	+0·10	19
8–9	+0·52	20	20–21	+0·23	14
9–10	+0·75	19	21–22	+0·38	17
10–11	+0·27	23	22–23	+0·65	20
11–12	+0·13	10	23–24	+0·64	15

The total number of stars used is in this case 407. Reading off from the curve and applying $-0''.41$ to correct for the mean discordance in N.P.D., when the stars are arranged in order of N.P.D., leads to the following table:—

R.A.	$\Delta\delta_a$ (1860-1870).	R.A.	$\Delta\delta_a$ (1860-1870).
h	"	h	"
0·0	+0·16	12·0	−0·07
1·0	+0·21	13·0	−0·09
2·0	+0·39	14·0	−0·14
3·0	+0·38	15·0	−0·08
4·0	+0·18	16·0	−0·13
5·0	+0·04	17·0	−0·18
6·0	−0·04	18·0	−0·24
7·0	−0·03	19·0	−0·29
8·0	+0·09	20·0	−0·24
9·0	+0·16	21·0	−0·09
10·0	+0·02	22·0	+0·11
11·0	−0·10	23·0	+0·20

V.—*The Melbourne Catalogue for* 1870 *and the Cape Catalogue for* 1880.

The comparison in R.A. of these two Catalogues, when the stars are arranged in order of N.P.D., is given in *Monthly Notices*, vol. xlv. pp. 300, 301, and the comparison in N.P.D., when the stars are arranged in the same order, in *Monthly Notices*, vol. xlii. pp. 20, 21. For the comparison in R.A., when the stars are arranged in order of R.A. and combined in groups extending each over one hour of R.A., we have:—

R.A.	Mean $\Delta\alpha$ 1870-1880.	Number of Stars.	R.A.	Mean $\Delta\alpha$ 1870-1880.	Number of Stars.
h h	s		h h	s	
0–1	−0·021	38	12–13	−0·002	49
1–2	−0·002	37	13–14	+0·006	42
2–3	+0·034	18	14–15	+0·003	44
3–4	+0·126	33	15–16	−0·039	33
4–5	+0·027	30	16–17	−0·014	41
5–6	+0·026	40	17–18	−0·006	37
6–7	+0·013	29	18–19	+0·037	47
7–8	+0·067	42	19–20	+0·002	36
8–9	+0·090	50	20–21	+0·054	36
9–10	+0·043	41	21–22	−0·055	29
10–11	+0·073	42	22–23	+0·013	46
11–12	+0·007	34	23–24	−0·013	42

Reading off from the reduction curve for the beginning of each hour of R.A., and applying $-0^{s}\cdot021$ to correct for the mean discordance in R.A. depending on N.P.D., the following table is formed:—

R.A.	$\Delta\alpha_{\alpha}$ (1870-1880).	R.A.	$\Delta\alpha_{\alpha}$ (1870-1880).
h	s	h	s
0·0	−0·033	12·0	−0·003
1·0	−0·028	13·0	−0·017
2·0	+0·004	14·0	−0·023
3·0	+0·043	15·0	−0·036
4·0	+0·045	16·0	−0·042
5·0	+0·017	17·0	−0·029
6·0	+0·006	18·0	−0·010
7·0	+0·024	19·0	0·000
8·0	+0·046	20·0	−0·002
9·0	+0·047	21·0	−0·019
10·0	+0·035	22·0	−0·032
11·0	+0·015	23·0	−0·031

Proceeding in exactly the same way with the N.P.D.s arranged in order of R.A., we get the following mean differences:—

R.A.	Mean $\Delta\delta$ 1870-1880.	Number of Stars.	R.A.	Mean $\Delta\delta$ 1870-1880.	Number of Stars.
h h	″		h h	″	
0–1	−0·61	38	12–13	−0·04	50
1–2	−0·56	35	13–14	+0·01	43
2–3	−0·67	18	14–15	−0·57	43
3–4	−0·78	32	15–16	−0·19	33
4–5	−0·79	31	16–17	−0·46	40
5–6	−0·69	40	17–18	−0·47	36
6–7	−0·57	29	18–19	−0·31	48
7–8	−0·10	43	19–20	−0·69	36
8–9	−0·86	50	20–21	−0·52	36
9–10	−0·62	41	21–22	−0·75	29
10–11	−0·17	42	22–23	−0·67	46
11–12	−0·14	34	23–24	−0·86	42

Applying $+\,0''\cdot50$ to correct for the mean discordance in N.P.D. depending on N.P.D., we have finally:—

R.A.	$\Delta\delta$ (1870–1880).	R.A.	$\Delta\delta$ (1870–1880).
h	"	h	"
0·0	−0·23	12·0	+0·40
1·0	−0·12	13·0	+0·42
2·0	−0·14	14·0	+0·26
3·0	−0·23	15·0	+0·15
4·0	−0·27	16·0	+0·13
5·0	−0·23	17·0	+0·08
6·0	−0·06	18·0	+0·06
7·0	+0·05	19·0	−0·01
8·0	−0·01	20·0	−0·10
9·0	−0·09	21·0	−0·16
10·0	+0·10	22·0	−0·20
11·0	+0·32	23·0	−0·25

Blackheath: May 13, 1886.

On the Proper Motion of Twenty-nine Telescopic Stars.

By J. L. E. Dreyer, Ph.D.

Of late years a considerable number of telescopic stars have been found to have Proper Motion. Not only has Argelander thoroughly investigated 480 stars, the great majority of which are below the sixth magnitude, and deduced the most probable values of their Proper Motions from all published observations of them, but every new Star Catalogue has added to the number of known Proper Motions, while not a few cases casually detected are to be found in the volumes of the *Astronomische Nachrichten*. I propose in this paper to discuss the Proper Motions of twenty-nine stars contained in the Second Armagh Catalogue of 3300 stars, as every contribution to our knowledge of one of the most important departments of Sidereal Astronomy must be of some value.

The Armagh Observations were made in the years 1859 to 1883 with the Mural Circle by Jones, to which in 1862 was added a telescope of seven inches' aperture by the late Mr. Th. Grubb. For further details as regards the instrument, the observations and their reduction, I may refer to the Catalogue itself, which I hope will be distributed in a few weeks. The working list was formed by selecting suitable stars from Baily's Lalande, which were supposed not to have been lately reobserved elsewhere. The mean places for 1875 resulting from the Armagh

Observations were compared with Baily's places, and wherever a difference appeared, exceeding upwards of a second of time in R.A. and eight or ten seconds in N.P.D., the voluminous list of corrections to Baily, given by Argelander in vol. vii. of the Bonn Observations, was in the first instance consulted. If this did not clear up the discrepancy, other modern Catalogues were examined in order to see whether the star was endowed with Proper Motion. In a great many cases it turned out that it was not, but whenever it seemed at all likely that there was Proper Motion, and that its amount had not been previously determined, all the materials available for this purpose were brought together. Lalande's observations were first reduced anew by means of Von Asten's excellent tables. The positions in Weisse's first Catalogue were also tested by a renewed reduction from the Königsberg Observations, but as the places found differed but very slightly from Weisse's, this precaution was not considered necessary in the case of Weisse's second Catalogue, as it is well known that it was prepared with considerably more care than the first one. All other modern Catalogues were searched and the positions were reduced to 1875, the epoch of the second Armagh Catalogue.

As the forthcoming Paris Catalogue, the Zone Catalogues of the *Astronomische Gesellschaft*, and probably also in some cases the new Brussels Catalogue, will soon furnish plenty of excellent positions for the stars in question, the Proper Motions in this paper are not to be considered as definitively determined. I have, therefore, simply used the places taken from the various Star Catalogues without applying systematic corrections for difference of equinox, &c. This omission can, however, hardly influence the results much, as the latter must for many years to come to a great extent depend on Bessel's and Lalande's observations; and considering the long interval of time which separates us from these, the systematic corrections to them become of less consequence. Whenever a star occurred in more than two Catalogues, in addition to the new Armagh Catalogue, the Proper Motion in both co-ordinates was computed by the method of least squares.

In the following the stars are designated by their numbers in the new Catalogue and in Baily's Lalande. For all stars north of 92° N.P.D. the magnitudes are taken from the *Durchmusterung*. The places are for 1875·0. Figures in brackets denote the number of observations; except where otherwise stated, each result depends only on one observation.

448 = LL. 6638, Mag. 8·0.

		h m s		° ′ ″
Lalande	1798·00	3 29 38·33	1798·00	64 24 34·6
Bessel	1828·10	39·11	1828·10	47·0
Armagh	1873·70	39·93 (4)	1874·29	54·9 (3)

Applying a Proper Motion = + 0ˢ·019 and + 0″·22 we get:

	h	m	s	°	′	″
Lalande	3	29	39·79	64	24	51·5
Bessel			40·00			57·3
Armagh			39·95			55·1

462 = LL. 6938, Mag. 7·0.

		h	m	s		°	′	″
Lalande	1799·88	3	38	15·27	1799·88	109	30	59·1
Arg. Oeltzen	1850·92			16·16	1850·92			59·5
Armagh	1871·96			16·74	1865·95			48·9 (2)

The two Armagh results in N.P.D. agree well *inter se*. It must be left for the future to decide whether there is P.M. in this co-ordinate. Applying a P.M. = + 0ˢ·024 we get:

	h	m	s
Lalande	3	38	17·07
Argelander			16·74
Armagh			16·81

521 = LL. 7892, Mag. 7·0.

		h	m	s		°	′	″
Lalande	1798·05	4	7	16·96	1798·05	77	58	4·2
Bessel	1823·01			18·17	1823·01			8·0
Rümker	1847·0			18·51 (2)	1847·0			8·4 (2)
Glasgow	1872·39			19·12 (2)	1874·29			11·6 (3)
Armagh	1876·20			19·35 (4)	1876·91			10·5 (5)

Giving the two last positions double weight we find P.M. = + 0ˢ·0270 and + 0″·080. Applying these we get:

	h	m	s	°	′	″
Lalande	4	7	19·04	77	58	10·4
Bessel			19·57			12·2
Rümker			19·27			10·6
Glasgow			19·19			11·7
Armagh			19·32			10·3

624 = LL. 9491, Mag. 7·0.

		h	m	s		°	′	″
Lalande	1799·88	4	55	54·67	1799·88	101	7	2·8
Bessel	1824·53			54·84 (2)	1824·53			8·0 (2)
Santini	1843·0			54·90	1843·0			7·7
Santini	1857·0			55·21	1857·0			1·4
Armagh	1879·02			55·23	1880·48			5·2 (2)

Bessel's single results in N.P.D. are 10″·8 and 5″·2. There is probably no P.M. in N.P.D. Giving all the Right Ascensions equal weight we find P.M. = + 0ˢ·0072, which gives:

	h m s
Lalande	4 55 55·21
Bessel	55·20
Santini	55·13
Santini	55·34
Armagh	55·20

677 = LL. 10394, Mag. 7·0.

		h m s		° ′ ″
Lalande	1798·06	5 25 3·62	1798·06	100 9 34·9
Bessel	1823·96	[3·08]	1823·96	47·0
Santini	1843·0	3·65 (2)	1843·0	52·9 (2)
Santini	1857·0	4·03 (2)	1857·0	54·9 (2)
Armagh		—	1860·00	55·4 (2)
Armagh	1873·96	4·14 (3)	1875·95	63·4 (4)

Rejecting Bessel's R.A. and giving all the others equal weight the P.M. is found = + 0ˢ·0081 and + 0″·354, which gives:

	h m s	° ′ ″
Lalande	5 25 4·24	100 10 2·1
Bessel	—	5·1
Santini	3·91	4·2
Santini	4·17	1·3
Armagh	—	0·7
Armagh	4·15	2·9

In N.P.D. the Proper Motion is well established, in R.A. it is somewhat doubtful. Lalande's R.A. depends, however, on two wire-transits agreeing well *inter se*.

729 = LL. 11196, Mag. 7·0.

		h m s		° ′ ″
Lalande	1798·06	5 48 51·97	1798·06	76 4 11·3
Bessel	1823·18	53·07	1823·18	27·1
Glasgow	1867·15	54·55	1867·15	51·8
Armagh	1871·11	54·70 (2)	1871·11	52·9 (2)
Glasgow	1877·05	54·64	1878·88	54·3 (2)
Armagh	1881·50	55·06 (2)	1881·65	56·9 (3)

As the Glasgow and Armagh observations are made at two epochs differing about ten years, I have used them separately. Giving the above positions equal weight the P.M. is found = + 0ˢ.0341 and + 0″·540. Applying these to the observations we have:

		h m s	° ′ ″
Lalande		5 48 54·59	76 4 52·8
Bessel		54·84	55·1
Glasgow	1867	54·82	56·0
Armagh	1871	54·83	55·0
Glasgow	1877–78	54·71	52·2
Armagh	1881	54·84	53·3

788 = LL. 12293–96, Mag. 7·4.

		h m s		° ′ ″
Lalande	1797·11	6 20 23·90 (2)	1797·11	53 25 57·8 (2)
Bessel	1829·20	23·45	1829·20	26 6·2
Armagh	1869·89	21·90 (5)	1866·73	26 13·4 (6)

Applying a P.M. of $-$ 0^s·031 and $+$ 0″·21 we get:

	h m s	° ′ ″
Lalande	6 20 21·49	53 26 14·2
Bessel	22·03	15·8
Armagh	21·74	15·1

985 = LL. 16494, Mag. 7·5.

		h m s	° ′ ″
Lalande	1794·11	8 18 9·90	90 44 0·8
Bessel	1824·05	10·33	14·4
Santini	1839·0	10·51	14·1
Lamont	1841·59	10·59 (10)	12·4 (10
Santini	1862·0	10·74	21·6
Göttingen	1868·65	10·62 (2)	20·0 (2)
Armagh	1879·18	10·95 (2)	21·8 (2)

Giving Lamont, Göttingen, and Armagh double weight, the P.M. is found = $+$ 0^s·0098 and $+$ 0″·228. Applying this we get:

	h m s	° ′ ″
Lalande	8 18 10·69	90 44 19·2
Bessel	10·83	26·0
Santini	10·86	22·3
Lamont	10·92	20·0
Santini	10·87	24·0
Göttingen	10·68	21·4
Armagh	10·91	20·9

1010 = LL. 16964, Mag. 6·5.

		h m s	° ′ ″
Lalande	1796·18	8 31 24·43	68 52 10·3
Bessel	1826·13	24·12	17·9
Armagh	1880·21	24·05	27·0

Assuming a P.M. = − 0ˢ·003 and + 0″·18 these positions become:

	h	m	s	°	′	″
Lalande	8	31	24·19	68	52	23·5
Bessel			23·97			26·7
Armagh			24·07			26·1

The P.M. is somewhat doubtful, especially in R.A., as Lalande has only one wire and gives no fraction of the second.

1294 = LL. 21358, Mag. 8·0.

		h	m	s		°	′	″
Lalande	1798·19	11	3	17·97	1798·19	86	52	3·8
Bessel	1823·28			17·36	1823·28			8·1
Lamont	1842·29			17·31	1842·29			2·7
Armagh	1851·28			16·96	1854·23			4·9 (2)
Schjellerup	1862·19			16·83	1862·19			3·8
Glasgow	1868·89			16·67 (3)	1868·89			6·3 (3)
Armagh	1883·26			16·53	1883·26			10·8

There seems to be no Proper Motion in N.P.D. Giving the Glasgow R.A. double weight, the P.M. is found = − 0ˢ·0172, applying which we get:

	h	m	s
Lalande	11	3	16·65
Bessel			16·47
Lamont			16·75
Armagh			16·55
Schjellerup			16·61
Glasgow			16·57
Armagh			16·67

1462 = LL. 23640, Mag. 7·2.

		h	m	s		°	′	″
Lalande	1791·25	12	32	37·77	1791·25	44	5	29·1
Arg. Oeltzen	1843·36			37·22	1843·36			37·6
Radcliffe	1851·8			37·14 (4)	1851·7			38·2 (5)
Armagh	1876·32			36·53 (2)	1868·34			37·1 (2)

It does not seem likely that there is Proper Motion in N.P.D. The amount of P.M. in R.A. depends to a great extent on the weight which is given to Lalande, and as he has only one wire and no fraction of the second, his R.A. may possibly be too small. Giving LL. weight = ½ and Glasgow and Radcliffe 2, the P.M. becomes = − 0ˢ·0178, applying which we get:

	h	m	s
Lalande	12	32	36·28
Argelander			36·66
Radcliffe			36·73
Armagh			36·55

1554 = LL. 24760–61, Mag. 7·2.

		h	m	s		°	′	″	
Lalande	1796·28	13	14	27·84	(2)	51	10	44·9	(2)
Armagh	1875·37			25·42				53·6	

This star does not occur in any other Catalogue. The P.M. must be nearly $-$ 0^s·031 and + 0″·11.

1727 = LL. 27055–56, Mag. 5·8.

		h	m	s		°	′	″	
Lalande	1794·85	14	44	39·15	(2)	65	34	15·4	(2)
Bessel	1826·41			39·70				20·6	
Armagh	1869·31			40·48				14·0	

With a P.M. = + 0^s·018 the Right Ascensions become:

	h	m	s
Lalande	14	44	40·59
Bessel			40·57
Armagh			40·58

1783 = LL. 27957, Mag. 6·5

		h	m	s			°	′	″	
Lalande	1798·44	15	14	21·82	1798·44		91	56	58·5	
Lamont	1851·87			20·74	(7)	1851·27		57	10·0	(6)
Göttingen	1868·27			20·40	(2)	1868·27			14·2	(2)
Armagh	1879·63			20·14	(4)	1879·63			17·1	(4)

Giving Lalande half weight the P.M. is found = $-$ 0^s·0222 and + 0″·265, which gives:

	h	m	s		°	′	″	
Lalande	15	14	20·12		91	57	18·8	
Lamont			20·23				16·3	
Göttingen			20·25				16·0	
Armagh			20·24				15·9	

$\mathfrak{d}$ 880 = LL. 29259, Mag. 7·9.

		h	m	s			°	′	″	
Lalande	1798·32	15	58	17·06		1798·32	90	48	46·2	
Lamont	1852·67			16·26	(11)	1852·67			51·9	(11)
Göttingen	1867·85			15·96	(2)	1867·85			54·6	(2)
Armagh	1875·38			15·94	(3)	1880·34			57·3	(2)

Giving Lalande half weight we find P.M. = − 0ˢ·0142 and + 0″·138, applying which the positions become:

		h m s	° ′ ″
Lalande		15 58 15·97	90 48 56·7
Lamont		15·94	55·0
Göttingen		15·86	55·6
Armagh		15·94	56·6

1912 = LL. 29752, Mag. 7·2.

		h m s	° ′ ″
Lalande	1794·33	16 12 52·85	57 54 22·7
Bessel	1826·44	53·12 (2)	14·2 (2)
Armagh	1877·98	53·73 (2)	53 57·2 (2)

Applying a P.M. = + 0ˢ·011 and − 0″·34 we get:

	h m s	° ′ ″
Lalande	16 12 53·74	57 53 55·3
Bessel	53·65	57·7
Armagh	53·70	56·2

1949 = LL. 30271, Mag. 7·2.

		h m s	° ′ ″
Lalande	1794·33	16 31 35·36	58 46 34·0
Bessel	1826·44	35·43	50·2
Armagh	1876·06	35·47 (5)	47 13·6 (5)

There is probably no P.M. in R.A. In N.P.D. it is = + 0″·48, which gives:

	° ′ ″
Lalande	58 47 12·7
Bessel	13·5
Armagh	13·1

2355 = LL. 35851, Mag. 5·5.

		h m s	° ′ ″
Lalande	1794·44	19 2 20·09	73 19 25·6
Rümker	1838·0	20·79 (4)	41·5 (4)
Armagh	1876·61	20·91 (8)	54·4 (8)

With a P.M. = + 0ˢ·005 and + 0″·34 we get:

	h m s	° ′ ″
Lalande	19 2 20·49	73 19 53·0
Rümker	20·97	54·1
Armagh	20·90	53·9

In R.A. the Proper Motion is very doubtful, as Lalande has only one wire, but in N.P.D. it seems well established.

2684 = LL. 39934, Mag. 7·0.

		h m s	° ′ ″
Lalande	1793·59	20 33 55·28	51 47 33·3
Bessel	1825·70	56·46	40·5
Armagh	1876·24	56·68 (5)	48·9 (5)

As Lalande has only one wire and no fraction of the second, it is as yet impossible to decide whether there is any P.M. in R.A. In N.P.D. a P.M. of + o″·17 gives:

	° ′ ″
Lalande	51 47 47·1
Bessel	48·9
Armagh	48·7

2732 = LL. 40484, Mag. 7·7.

		h m s		° ′ ″
Lalande	1794·50	20 50 26·72	1794·50	88 44 58·8
Piazzi	1802·68	26·55 (6)	1802·68	45 7·4 (6)
Bessel	1821·63	[27·58]	1821·63	6·4
Taylor	1837·0	26·55 (2)	1837·0	13·7 (2)
Lamont	1849·20	26·44 (13)	1849·20	17·1 (13)
Armagh	1865·66	26·38	1867·57	20·5

Bessel's R.A. is doubtless 1ˢ·0 too great; it has not been used. Giving Taylor's position weight 2 and Lamont's weight 3, the P.M. is found = − o^{s}·0041 and + o″·264, which gives:

	h m s	° ′ ″
Lalande	20 50 26·39	88 45 20·1
Piazzi	26·25	26·5
Bessel	26·36	20·5
Taylor	26·39	23·7
Lamont	26·33	23·9
Armagh	26·34	22·5

2741 = LL. 40604–6, Mag. 7·8.

		h m s		° ′ ″
Lalande	1794·14	20 52 11·42 (2)	1794·14	47 35 48·8 (2)
Bessel	1825·76	11·73	1825·76	45·5
Armagh	1871·67	12·65 (4)	1871·66	33·5 (1)

Adopting a P.M. = + 0ˢ·175 and − 0″·23 we get:

		h	m	s		°	′	″
Lalande		20	52	12·83		47	35	30·2
Bessel				12·59				34·2
Armagh				12·71				32·7

2835 = LL. 41700, Mag. 8.5.

		h	m	s		°	′	″
Lalande	1794·61	21	20	25·88	1794·61	85	5	0″7
Bessel	1821·66			26·69	1821·66			10·1
Lamont	1841·64			26·77	1841·64			14·6
Armagh	1874·24			26·79 (2)	1873·74			24·8

Lalande has only one wire and no fraction of the second. There can hardly be any Proper Motion in R.A. The observations of N.P.D. give a P.M. = + 0″·297, applying which we get:

	°	′	″
Lalande	85	5	24·6
Bessel			25·9
Lamont			24·5
Armagh			25·2

2883 = LL. 42286, Mag. 7·1.

		h	m	s		°	′	″
Lalande	1793·64	21	35	25·05		63	48	40·3
Bessel	1825·66			25·59				48·3
Armagh	1877·78			27·05 (4)				50·1 (4)

Adopting a P.M. of + 0ˢ·026, the Right Ascensions become:

	h	m	s
Lalande	21	35	27·16
Bessel			26·87
Armagh			26·98

Lalande has two wires, but they differ by 0ˢ·6. Still, the P.M. in R.A. seems certain. Lalande is probably 10″ wrong in P.D.

2933 = LL. 42843–44, Mag. 7·2.

		h	m	s		°	′	″
Lalande	1794·61	21	52	13·06 (2)	1794·61	86	48	38″6 (2)
Bessel	1821·66			12·77	1821·66			42·6
Santini	1839·0			12·21 (2)	1839·0			46·5 (2)
Lamont	1847·78			12·03	1847·78			42·7
Glasgow	1870·80			11·52 (3)	1870·80			51·4 (3)
Armagh	1875·17			11·56 (4)	1875·68			52·3 (5)

From these we find the P.M. = − 0ˢ·0202 and + 0″·179, which gives:

	h	m	s	°	′	″
Lalande	21	52	11·44	86	48	53·0
Bessel			11·69			52·1
Santini			11·48			52·9
Lamont			11·48			47·6
Glasgow			11·44			52·2
Armagh			11·56			52·2

3064 = LL. 44458–59, Mag. 7·5.

		h	m	s		°	′	″
Lalande	1794·61	22	37	27·82 (2)	1794·61	86	47	12·4 (2)
Bessel	1821·73			28·54 (2)	1821·73			5·4 (2)
Yarnall	1858·8			28·59 (2)	1853·9		46	51·5 (2)
Schjellerup	1861·97			28·54	1861·97			51·6
Glasgow	1871·70			28·72 (2)	1874·80			45·4 (4)
Armagh	1874·72			28·80 (5)	1874·72			47·1 (5)

Giving all equal weight, the P.M. is found = + 0ˢ·0104 and − 0″·329, which gives:

	h	m	s	°	′	″
Lalande	22	37	28·66	86	46	46·0
Bessel			29·09			47·9
Yarnall			28·76			44·6
Schjellerup			28·68			47·3
Glasgow			28·75			45·3
Armagh			28·80			47·

Bessel's observations were made on October 21 and September 1, 1821; the R.A.s differ by 0ˢ·33. If the second observation were left out, the agreement would be a little better in R.A.

3083 = LL. 44738, Mag. 7·2.

		h	m	s	°	′	″
Lalande	1797·74	22	45	24·30	38	36	36·4
Argelander	1842·45			25·34 (3)			29·5 (3)
Armagh	1878·91			25·44			21·2

Lalande has only one wire and no fraction of second; his R.A. is therefore probably 1ˢ·0 too small, and there would then be no P.M. in R.A. In N.P.D. a P.M. = − 0″·21 represents the observations as follows:

	°	′	″
Lalande	38	36	20·2
Argelander			22·7
Armagh			22·

3111 = LL. 45028, Mag. 7·9.

		h	m	s		°	′	″
Lalande	1795·69	22	55	18·47	1795·69	94	30	23·0
Yarnall	1865·80			20·55 (7)	1865·70			43·3 (3)
Dunsink	1881·75			21·16 (3)	1881·75			47·0 (3)
Armagh	1883·93			21·01	1883·93			49·9

Giving the first and the last result half weight, the P.M. is found = + 0ˢ·0307 and + 0″·278, which gives:

	h	m	s	°	′	″
Lalande	22	55	20·90	94	30	45·0
Yarnall			20·83			45·9
Dunsink			20·95			45·1
Armagh			20·74			47·4

3163 = LL. 45680, Mag. 7·5.

		h	m	s		°	′	″
Lalande	1795·69	23	13	45·47	1795·69	94	35	44·1
Bessel	1822·73			45·96	1822·73			53·0
Santini	1843·0			46·22	1843·0			[64·5]
Armagh	1853·86			46·66	1850·70			59·2
Yarnall	1858·70			46·41 (3)	1861·80			56·4 (3)
Schjellerup	1862·95			46·74	1862·95			55·3
Glasgow	1868·80			46·62 (3)	1870·15			57·3 (3)
Armagh	1882·79			46·89	1882·79			59·0

Santini is doubtless 10″·0 wrong in P.D. Leaving this out, the P.M. is found = + 0ˢ·0163 + 0″·140, which gives (after correcting Santini by − 10″):

	h	m	s	°	′	″
Lalande	23	13	46·76	94	35	55·2
Bessel			46·81			60·3
Santini			46·74			59·0
Armagh			47·00			62·6
Yarnall			46·68			58·6
Schjellerup			46·94			57·0
Glasgow			46·72			58·0
Armagh			46·76			57·9

3218 = LL. 46343–44–45, Mag. 6·8.

		h	m	s		°	′	″
Lalande	1796·47	23	33	11·13 (3)	1796·47	62	27	28·8 (3)
Bessel	1827·75			12·10	1827·75			23·9
Armagh	1868·89			12·75	1867·80			13·0 (2)

Adopting a P.M. = + $0^s.020$ and − $0''.24$ we get:—

	h m s	° ′ ″
Lalande	23 33 12·70	62 27 10·0
Bessel	13·04	12·6
Armagh	12·87	11·3

In addition to these Proper Motions, a number of other more doubtful cases have been found, which are mentioned in the Notes to the new Armagh Catalogue. These are: LL. 4381, 6106, 6254, 6275, 8618, 11374, 14264, 35817, 37766, 44738. These, as well as several stars with Proper Motion announced on a former occasion (*Copernicus*, vol. ii. pp. 148–151) I would recommend to the attention of meridian observers.

Micrometric Observations of Nova Andromedæ, made at the Observatory, Dunsink. By Sir R. S. Ball.

I see that Professor Asaph Hall has made a series of measures to try if *Nova Andromedæ* has an appreciable Parallax. Perhaps it may be of interest in connection with this subject to publish the following measurements which I made here last autumn with the South Equatorial. The instrument and mode of observing have been described in the various parts of the "Dunsink Observations."

From *Nova Andromedæ* to Star, 11th mag. *s.f.*

1885.	Dist.	Pos.	1885.	Dist.	Pos.
	″	° ′		″	° ′
30 Sep.	229·7	156 33	1 Dec.	228·3	155 35
3 Oct.	230·2	156 25	2 „	229·5	157 3
4 Nov.		156 17	9 „	229·4	156 36
30 „	228·8	155 29			

From *Nova Andromedæ* to Star, 10th mag. *p.*

1885.	Dist.	Pos.	1885.	Dist.	Pos.
	″	° ′		″	° ′
21 Sep.	110·0	262 0	30 Nov.	109·5	260 36
30 „	110·6	261 6	1 Dec.	109·7	261 22
3 Oct.	108·9	261 46	2 „	108·7	262 7
27 „	109·0	262 41	7 „	109·8	260 47
28 „	109·8	263 19	8 „	109·1	261 13
4 Nov.	109·9	262 17	9 „	108·3	261 35

Dunsink Observatory,
1886, *May* 13.

Observations of the New Star in Orion. By J. E. Gore.

The following are all my observations of this star since January 16, the last observation given in my paper in the *Monthly Notices* for January 1886. The comparison stars are as follows, and their magnitudes were measured for me by Professor Pickering with the meridian photometer at Harvard Observatory:

	Mag.
57 Orionis	5·90
(*b*) = Lalande 11088	6·09
(*c*) = D.M. + 20°, 1156	6·57

Observations of Nova Orionis.

Date of Observation.	Estimated Magnitude.	Notes.
1886, Jan. 23	7·5	Moonlight.
Jan. 29	8·3	More than one magnitude less than (*c*); no moon.
Feb. 3	8·5	Clear moonless sky. *Nova* about equal to a small star nearly due north of it.
Feb. 10	8¾	Small with binocular; moonlight.
Feb. 19	8¾	Faint with binocular; moon rising, 6·55 P.M.
Feb. 22	8·9	Faint with binocular; clear moonless sky.
Mar. 3	9	Faint with binocular; clear moonless sky.
Mar. 6	—	Only seen by glimpses with binocular; clear sky; no moon, 9·25 P.M.
Mar. 25	—	Glimpsed at intervals with binocular; very clear sky; no moon.
April 7	—	Only doubtfully glimpsed with binocular; very clear sky; moon setting.
April 28	—	*Nova* not visible with binocular; very clear sky.

The above observations were made with the binocular with which the star was discovered. From a comparison of the sky with Argelander's magnitudes, I find that the *minimum visible* of this binocular in a clear moonless sky is 8·9 or 9·0 mag. in the scale of the *Durchmusterung*, so that on March 6 the star could not have been much, if anything, brighter than 9·0 mag. My observations, therefore, show a diminution of light from December 13 to March 6 of about 3 magnitudes. Professor Pritchard finds a decrease of only half a magnitude to March 10 (*Monthly Notices*, March, 1886). Mr. Gemmill, on February 24, estimated the star as 9½ magnitude with 3¼-inch refractor (*English Mechanic*, April 16, 1886), and in a letter from a well-known observer in America, dated February 5, 1886, he estimated the *Nova* about 8 magnitude at that date. My observations have also been confirmed by Mr. H. M. Parkhurst, of New York, and by photometric observations at Harvard Observatory.

Ballysodare, Co. Sligo:
May 4, 1886.

Observations of the Companion of Sirius made at the Dearborn Observatory, Chicago, U.S.A. By Prof. G. W. Hough, Director.

(*Communicated by the Secretaries.*)

Date.	P.	S.
	°	″
1886·066	28·7	7·31
·096	29·5	7·25
·099	28·8	7·10
·125	29·1	7·14
·128	28·7	7·21
·145	28·9	7·11
·164	28·8	7·23
·167	28·1	7·20
·170	28·2	7·22
·175	28·3	7·17
·186	29·0	7·25
·203	28·5	7·31
Mean Results 1886·144	28·7	7·21 (12 obs.)

Note on a remarkable Sun-spot. By B. J. Hopkins.

While examining the Sun's surface on April 24 at $20^h\ 55^m$, I had the good fortune to observe the somewhat rare phenomenon of a coloured sun-spot. At the time there were in all five spots on the solar disc, arranged in two groups; the largest spot being the one presenting the abnormal appearance, which in size was equal to all the others put together, and comprised within its single penumbra four distinct umbræ.

Coloured spots have been occasionally seen by different observers, but this spot differed from those hitherto observed, in that it was only two out of its four umbræ which presented an appearance different to what is usually seen. Observed with a three-inch refractor and an Huyghenian eye-piece magnifying fifty diameters, the spot referred to presented the extraordinary spectacle of being of two colours, its two southern umbræ being of the ordinary blackish hue, while the two northern umbræ were of a reddish-brown. So marked, indeed, was the colour, that never having seen such a phenomenon before—though I have observed several scores of spots in the course of the last ten years—I was at first inclined to attribute the unusual appearance to some defect in the instrument, or to some temporary imperfection of my sight. I therefore changed the eye-piece I was using for another negative of double the power, with the result that the only difference observable besides the in-

creased magnification was that one of the umbræ was more decidedly coloured than its companion.

Still the appearance was to me so unusual that I remained half inclined to doubt the evidence of my senses, and regard it as merely an optical illusion. To decide the question I called my wife, who upon looking through the telescope immediately remarked the colour of the spot, comparing it to that of rusty iron.

How long before I began observing, the spot had presented this abnormal appearance I am unfortunately unable to say; but by $21^h\ 15^m$, or twenty minutes after I first looked at the Sun, all trace of the unusual colour had vanished. I may say in conclusion that the penumbra of the spot presented nothing unusual in its appearance; it was only the umbra that was coloured.

Forest Gate, E.

Jupiter's Third Satellite in Transit, April 11, 1886.

By W. F. Denning.

The satellite crossed the planet as a dusky spot, except when near the limbs, where it was visible as a bright spot. The following notes were made during the progress of the phenomenon. The times are only approximate:—

$9^h\ 33^m$ Sat. III. increasing in faintness and drawing very close to the N.E. limb. It seems slightly overshadowed, especially on the side nearest *Jupiter*, where the shading reminds one of the penumbra falling on the Moon prior to a lunar eclipse.

9 49. III. in contact with exterior edge of disc, the satellite is much brighter than the planet's limb, though itself involved in a delicate veil of shade.

9 58. Ingress complete. Satellite growing perceptibly fainter though still far brighter than the limb, on which it is projected as a bold, pearl-like spot just within the periphery.

10 7. III. now quite invisible. It rapidly lost brightness until its tone became indistinguishable from that of the surface. The satellite is evidently in course of transition from a bright to a dark spot. The seeing not very good.

10 48. Light cirrous clouds partly hindered close observation until this time, then III. was immediately seen as a pale dusky spot, rather small, and traversing a bright zone separating two dark belts in the planet's north temperate zone, and lying midway between the N. equatorial belt and N. limb. The S. side of the satellite is evidently darker than the opposite side.

10 55. The satellite assuming a deeper tone. The air has now become steadier; definition very sharp.

As III. reached mid-transit it became still more obvious, and seemed elongated S.S.E. to N.N.W. The satellite was of a light brown colour, and not nearly so dark as I have seen it when the chord traversed has been nearer the equator.

During the later phases of the occurrence the seeing became very fine, and the complex details of the markings came out very numerously and distinct. The N. equatorial belt showed a large white spot interrupting its continuity. This was central at $11^h\ 14^m$, and immediately following it there was a great thickening of the belt, extending itself far to the eastwards. This belt was divided lengthwise by a narrow bright line. At times, when a perfectly steady image impressed itself on the eye, a large extent of the N. polar region was observed furrowed with narrow dark belts. They were parallel in direction, though not equidistant from each other or of the same relative distinctness. Close to the pole their distinctive outlines were lost in a confused shading.

The double belt N. of the great N. belt was broad and somewhat faint, with decided condensations here and there. As to the great S. belt its equatorial borders were literally studded by bright spots with intervening and somewhat ill-defined dark patches. From the latter there were delicate wisps of dark-grey matter running to the N.E. and commingling with a delicate, undulating belt at the equator. These dusky markings on the S. side of the equator nearly always trend in this direction, as if their material were evolved from the belt, and in flowing to lower ground at the equator deviated to the E. by the effects of the rapid axial rotation which carries this part of the surface over 458 miles per minute.*

At $11^h\ 54^m$ the shadow of Satellite III. had entered well upon the N.E. limb, and the contrast with the satellite itself, now between the central meridian and N.W. limb, was most marked. The shadow was much larger and jet black, like an ink spot on white paper. One might readily imagine the appearance due to a perforation in the planet through which the dark depths of the sky beyond could be seen. The satellite, though still perceptible as a dusky spot of increasing faintness, was very inconspicuous compared with the remarkably bold aspect of its shadow.

Bristol: April 19, 1886.

* I deduce this rate from the rotation of the equatorial white spot = 590·2 minutes, and adopting the equatorial diameter of Jupiter as 86,000 miles.

Meteor Shower of Halley's Comet. By W. F. Denning.

There is perhaps no star-shower which has, in recent years, stood so much in need of re-observation as the brilliant display of Aquariads discovered by Lieut.-Col. Tupman while cruising off the east coast of Sicily on the mornings of May 1 and 3, 1870. But the radiant point at 325°–2½°, 5° preceding *α Aquarii*, as determined on that occasion, does not rise in our latitude until just before daylight, so that the only prospect of recovering the shower was by morning watches, necessarily rendered very brief and imperfect by the prevailing twilight of the season. These circumstances enabled the shower to elude subsequent observation.

Heis had recorded that on May 2, 1848, he observed many falling stars with bright streaks ("viele Sternschnuppen mit hellen Schweifen"), but it is extremely uncertain whether this relates to a veritable pre-apparition of the special shower witnessed by Col. Tupman.

Observing just before daylight on May 4, 1878, Mr. Corder registered three meteors of this stream. He describes them as notable for great length of path, and found the radiant at 334°–1° (*Observatory*, vol. ii. p. 103). A few other paths observed by him at various times afterwards led him to place the centre at 334°–5°, April–May (*Monthly Notices*, xi. p. 135).

Contemporary with Col. Tupman's observations in 1870, a number of diligent observers were recording meteors in the clear Italian sky, and the materials they accumulated were published at Milan in 1882. I projected 229 paths given in this Catalogue for the interval April 29—May 6, between 13^h and $15\frac{1}{2}^h$, and found that about forty-five of these belonged to the display of Aquariads. The meteors were very bright, with streaks and singularly long trajectories, and their radiant point was indicated at about 335°–9° (*Monthly Notices*, xliii. p. 111–14). This value exhibited such a large discordance with that determined by Col. Tupman that it became more than ever necessary to secure new observations. This was rendered all the more imperative from the suggestive resemblance in date and place of the meteor shower with the computed radiant for Halley's comet (1835, iii.) at its nearest appulse to the earth's orbit on May 4, twelve days preceding its passage through the descending node. Prof. Herschel gives the point 337° ± 0°, May 4, as the theoretical radiant of meteoric particles from this comet (*B.A. Report on Luminous Meteors*, 1874, p. 349), and points out that the agreement with Col. Tupman's shower of 1870 is a significant one, notwithstanding the difference of 10° or 12° in their radiant points.

At the return of this shower in the present year we had a succession of very clear nights, and (the moon being absent) I obtained observations on April 25, 26, 27, 30, May 1, 3, 4, 5, 6, 8 and 9: 117 shooting stars were recorded in watches extending

over 27½ hours. On the whole, I found meteors extremely rare, the horary rate being about four. On May 3, though the atmosphere was highly transparent and the stars unusually brilliant during the five hours I continued to watch, only twenty-one were seen. Again, on May 5, not more than twenty-four were counted in four hours. I have frequently seen meteors four or five times as numerous as this on clear nights in the autumn.

On April 30 and following nights the Aquariads were well observed, and formed the best display of the epoch. I found them fairly conspicuous meteors with dense, flaky streaks, and their lines of flight covered extensive arcs. The average length of twelve paths was 39°·0, whereas the average length of ordinary meteors, derived from all my observations, is 11°·2. (The average of the forty-five conformable tracks registered by the Italian observers in 1870 was 34°·7.) I recorded the motions as ranging between slow and swift. These Aquariads are remarkable for their long, graceful flights, rather than for any extreme degree of visual velocity, though were the radiant higher, they would doubtless appear much swifter, and their apparent paths must cease to exhibit abnormal length.

The bright streaks generated by these meteors are very useful as affording the means of recording their directions with great accuracy. From twelve paths I find the radiant at 337° − 2½°, which must be within 2° of probable error. Nine of the meteors agree well with this position, and the three remaining tracks pass within a few degrees of it, but the radiant may be diffuse to the extent of 5° or 7°, for I cannot otherwise explain the three slightly discordant meteors, the directions in each case having been well observed.

The radiant point of this shower is therefore close to *η Aquarii* and 11° W. of a mean of three positions given by Col. Tupman. It agrees so closely with the radiant of Halley's comet, and among other favouring circumstances, the shower is one of such pronounced and definite character, that the identity of the two orbits seems placed beyond doubt. Comparing the radiants, we have the following figures:—

Halley's Comet	May 4	337° ± 0°
Tupman's Aquariads	April 30–May 6	337 − 2½

The maximum occurs on May 6 according to my recent observations. At the time of nearest approach to the Earth the comet's orbit is 0·061 (Sun's distance = 1) below the Earth, which is equivalent to nearly 5¾ millions of miles. This interval is relatively inconsiderable when we remember to what enormous distances from the nucleus the material of the comet probably extends. The facts appear to present another excellent instance of agreement between a periodical comet and a very conspicuous meteor shower. The latter should now be specially looked for at observatories much further south, where the conditions are more favourable. In our latitude the radiant at 337° −2½° does

not clear the horizon until about $13^h\ 45^m$, when daybreak is already becoming strong in the N.E. sky. At southern stations, however, there would be a longer interval available for observation, and the greater elevation of the radiant must greatly enhance the richness of the shower. But while the low altitude of the radiant, as seen from this country, detracts from the numerical strength of the display, it has the effect of increasing the conspicuous aspect of the meteors, and their long flights right across the firmament create an impression not soon forgotten.

The following are the observed paths of eleven Aquariads recently seen here, and one recorded in 1880:—

No.	Date.	h	m	Mag.	Path From α_o	Path From δ_o	Path To α_o	Path To δ_o	Length of Path.	Appearance.
1	1880, May 2	14	23	3	324	+14	311	+28	18	Slowish; streak.
2	1886. Apr. 30	14	48	3	346	+30	355	+54	25	Swift; streak.
3	May 1	14	37	3	300	− 2	280	− 0½	19	Swift; streak
4	3	14	31	3	345⅓	+43	135	+68	66	Slowish; streak.
5	4	14	20	2	310	+ 3	270	+11	41	Slowish; streak.
6	5	14	6	4	334½	+28	327	+68	40	Slow; streak.
7	5	14	18	2	301	−16	270	+23½	30	Swift; streak.
8	6	13	55	4	323	+30½	224	+79	62	Slowish; streak.
9	6	14	11	2	306½	+21	202	+31	87	Slow; streak.
10	6	14	28	5	299	+24	274	+33	22	Rather swift.
11	6	14	32	4	334	+22½	332	+33	10½	Swift; streak.
12	6	14	36	3	301	+19½	250	+38½	47	Slowish; streak.

May 2 and 7 were cloudy, and May 8 clear only in the early part of the night. On May 9 I obtained a good view of the eastern sky between 14^h and 15^h, and saw six meteors, but the radiant in *Aquarius* gave no sign of continued activity.

I cannot account for the wide difference between my radiant point and that adopted by Col. Tupman. To get a good centre I took the precaution to watch the S.E. and N.E. sky alternately, so as to secure paths placed nearly at right angles. If Col. Tupman observed these Aquariads chiefly in the southern sky the motions would be in Right Ascension, and would give the Declination of the radiant well, while the R.A. would probably be doubtful to the extent of 10° or 15°. This is the most feasible explanation of the discordance that occurs to me.

The fine shower of Aquariads which, with early Perseids, form the well-defined meteoric epoch of July 27–30, have a radiant point at about 340°–12°, near *δ Aquarii*, and ten degrees south of the May Aquariads.

My late observations supply definite evidence of a considerable number of minor radiant points. The best of these are at 234°+10°, near *α Serpentis*, at 254°−21°, near *ρ Ophiuchi*, at 189°+58°, near *ε Ursæ Majoris*, and at 239°+46°, on the N.W. borders of *Hercules*.

Bristol: May 11, 1886.

Observations of Comets d 1885 (*Fabry*), *e* 1885 (*Barnard*), *and a* 1886 (*Brooks*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of Declination.

Comet d 1885.

1886.	Greenwich Mean Solar Time.	Observer.	☄−✱ R.A.	Corr. for Par. and Refract. in R.A.	☄−✱ N.P.D.	Corr. for Par. and Refract. in N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp Star.
	h m s		m s	s	′ ″	″		h m s	° ′ ″	
April 9	15 21 31	H. T.	+2 42·83		− 1 24·6		3			*a*
	15 21 31		+2 33·90		+ 8 36·6		3			*b*

Comet e 1885.

April 25	9 36 49	H.	+6 22·70	−0·10	+ 5 28·8	+ 5·0	4	1 40 13·35	50 5 32·1	*c*
	9 40 44		−7 30·20	−0·90	+11 10·8	+32·7	1	1 40 15·52	50 6 9·7	*d*
	9 59 45		+4 12·80	+0·24	− 6 25·4	−22·2	1	1 40 6·12	50 5 10·7	*e*
26	9 14 24	L.	+6 44·50	+0·48	− 7 45·2	−17·0	1	1 40 35·79	49 52 8·7	*f*
	9 18 57		+7 16·75	+0·28	− 1 37·9	− 9·9	2	1 40 38·58	49 51 59·2	*g*
May 3	13 33 45	H. T.	−0 33·88	−0·43	− 3 30·1	−11·1	6	1 38 57·03	49 31 44·3	*h*

Comet a 1886.

1886.	Greenwich Mean Solar Time. h m s	Observer.	♂−✱ R.A. m s	Corr. for Par. and Refract. in R.A. s	♂−✱ N.P.D.	Corr. for Par. and Refract. in N.P.D.	No. of Comp.	Apparent R.A. h m s	Apparent N.P.D. ° ′ ″	Comp. Star.
April 29	11 35 9	H. T.	−1 2·25	−0·22	− 1 36·1	− 6·0	2	0 36 55·38	28 41 50·1	*i*
	11 35 9		−1 7·50	−0·22	− 3 9·8	− 6·1	2	0 36 57·16	28 41 58·3	*k*
	11 35 9		−7 30·75	−0·22	− 7 4·6	− 6·5	2	0 36 56·33	28 41 52·6	*l*
30	9 12 33		+2 25·50	+0·14	+ 6 19·8	− 5·3	2	0 44 3·61	29 8 36·9	*m*
May 1	9 49 54	A. D.	+5 34·20	+0·07	+10 12·2	− 4·9	5	0 55 54·03	29 21 52·3	*n*
2	9 42 29	L.	+0 12·83	+0·08	− 5 22·4	− 6·7	3	0 59 17·89	30 12 56·8	*o*
	10 4 13		+1 53·50	+0·07	− 2 23·6	− 6·4	1	0 59 30·29	30 14 11·7	*p*
3	10 1 39	A. D.	+6 47·67	+0·04	+ 2 44·2	− 5·8	3	1 6 40·19	30 47 51·7	*q*
	10 10 27		−1 6·00	+0·02	− 2 59·9	− 6·6	5	1 6 42·20	30 48 7·6	*r*

Mean Places of Comparison Stars.

Star's Name.	R.A. 1886·0. h m s	N.P.D. 1886.0. ° ′ ″	Authority.
(*a*) Arg. Zone +39° No. 5099 (?)	23 26 25·66	49 51 3·3	Bonn Observations, vol. iv.
(*b*) Arg. Zone +40° No. 5099 (?)	23 26 40·86	49 41 51·3	,, ,, ,,
(*c*) τ Andromedæ	1 33 51·29	50 0 2·7	Greenwich 9-year Catalogue.
(*d*) Groombridge 400	1 47 47·14	49 54 18·3	Radcliffe.
(*e*) W. B. (*2*) I. 785	1 35 53·58	50 11 50·2	Weisse's Bessel (2).

Star's Name.	R.A. 1886·0.	N.P.D. 1886·0.	Authority.
	h m s	° ′ ″	
(*f*) τ Andromedæ	1 33 51·29	50 0 2·7	Greenwich 9-year Catalogue.
(*g*) Lalande 3024	1 33 22·03	49 53 38·7	Lalande.
(*h*) W. B. (2) I. 863	1 39 31·73	49 35 14·9	Weisse's Bessel (2).
(*i*) Arg. Zone + 61° No. 162	0 37 58·35	28 43 22·5	Bonn Observations, vol. v.
(*k*) Arg. Zone + 61° No. 164	0 38 5·38	28 45 4·5	,, ,, ,,
(*l*) Oeltz. Arg. (N) 801	0 44 27·83	28 48 54·1	Oeltz. Arg. (N).
(*m*) Oeltz. Arg. (N) 746–47	0 41 38·46	29 2 13·7	,, ,,
(*n*) Lalande 1562	0 5 20·26	29 11 35·3	Lalande
(*o*) Arg. Zone + 59° No. 180	0 59 5·46	30 18 16·3	Bonn Observations, vol. v.
(*p*) Arg. Zone + 59° No. 176	0 57 37·20	30 16 32·0	Rümker.
(*q*) Arg. Zone + 59° No. 181	0 59 52·93	30 45 3·5	Bonn Observations, vol. vi.
(*r*) Arg. Zone + 58° No. 201	1 7 48·66	30 51 4·5	,, ,, ,,

Notes.

April 9. Bright condensation at the head and a long tail. No striations or other detail discernible with a power of 310.
April 29. Comet fairly bright, but no nucleus.

The observations are corrected for parallax and refraction. The initials H. T., A. D., L., and H. are those of Mr. Turner, Mr. Downing, Mr. Lewis, and Mr. Hollis respectively.

Royal Observatory, Greenwich:
1886, *May* 12.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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J. W. L. GLAISHER, M.A., F.R.S., President, in the Chair.

Commander James Llewellyn Heane, F.R.G.S., Alte Burg, bei Gross Berkel, Hanover,

was balloted for and duly elected a Fellow of the Society.

On Delaunay's Method for Calculating Terms of Long Period in the Motion of the Moon. By E. Neison.

In the *Monthly Notices* for March 1878 (vol. xxxviii. pp. 268–279), I drew attention to an important discrepancy between the theoretical investigations of Hansen and Delaunay upon which they had founded their evaluations of the terms of long period in the motion of the moon arising from the disturbing action of the planet *Venus*; and I pointed out that it seemed very doubtful whether Delaunay's investigations were really complete, for there appeared to be strong evidence that he had neglected the very terms from which Hansen had derived the large values found by him for the *Venus* terms.

It is well known that Hansen himself never admitted the accuracy of these investigations of Delaunay, but always maintained that they were erroneous owing to some imperfection in the method, though he does not seem ever to have definitely pointed out the manner in which he believed it to be imperfect. It is known that he was in communication with Leverrier, and furnished him with reasons sufficiently strong to bring Leverrier to the same opinion. Delaunay's method, however, differs completely from those employed in their researches by both Hansen and Leverrier, and though its fundamental theoretical principle is beautifully simple and rigidly accurate, there are involved a very complex series of transformations and approximations before

it is applicable to the actual calculation of the lunar theory. And a study of their published papers has led me to the view that though both Hansen and Leverrier had convinced themselves that Delaunay's method had led him to imperfect results, neither had considered it necessary to obtain that mastery over its complex transformations and their involved approximations that would alone have enabled them to indicate the exact point where it became imperfect.

I reproduce here from my Paper of March 1878 the reasons which led me to the opinion that Delaunay's method is incomplete:

"In the *Memoirs of the Royal Astronomical Society*, vol. xvi. Hansen has published the only existing details of his method of computing these inequalities, and on page 476 there occurs the following passage. Speaking of the term whose argument is denoted by him by $(g-18g''+16g')$, and whose value as far as the first power of the disturbing forces he had just computed, Hansen says: 'Cependant le cube des forces perturbatrices ou plutôt le produit du carré et du cube de la force perturbatrice du soleil par la force perturbatrice de *Venus*, ajoute une quantité sensible à ce coefficient, et rend en même temps sensible le coefficient de l'argument $(8g''-13g')$, qui, en tenant seulement compte de le première puissance de la force perturbatrice, serait insensible dans le mouvement de la lune.' Delaunay appears to me to have entirely overlooked the real bearing of this important statement, for I think it clearly defines from whence Hansen obtained the large value for the coefficient of the argument $(8g''-13g')$, which was found to be insensible by Delaunay.

"The direct action of the planet *Venus* in producing perturbations in the motion of the Moon may be analytically represented by a particular disturbing function made to form part of the complete disturbing function which represents the action of every disturbing body on the Moon. This particular disturbing function depends on the undisturbed geocentric co-ordinates of the Moon and *Venus* and on the complete perturbations of the Moon. By neglecting the second and higher powers of the mass of *Venus*, this particular disturbing function is developed in terms of the heliocentric elliptic co-ordinates of *Venus* and the Earth, the geocentric elliptic co-ordinates of the Moon, and of the different powers of the perturbations in the motion of the Moon which are produced by the disturbing action of the Sun. Delaunay has exclusively confined himself to this portion of the complete disturbing force when finding the direct action of *Venus* upon the Moon, and as far as the first power of the disturbing forces, it is evident that this is the only portion which need be considered. As far as the first power of the disturbing forces, Delaunay finds a value for the term $(g-18g''+16g')$ which is sensibly identical with that found by Hansen under the like conditions. For the term $(8g''-13g')$, under these conditions, Delaunay finds its coefficient to be insensible. In this also

he agrees with Hansen, as the paragraph which has been quoted will show. To this order Delaunay's investigations must be complete, and to this order both Hansen and Delaunay have obtained identical results.

"When Delaunay takes into consideration the effect of the different powers of the perturbations in the motion of the Moon arising from the disturbing action of the Sun, in all cases he considers the effect of the first power of these perturbations, and in one particular term he includes the second power of these perturbations. Delaunay shows that these terms do not materially augment the value of the two terms of long period. Granting that these results are perfectly accurate—and there can be no real doubt about their accuracy—is there any real discrepancy between them and those which Hansen obtained? It cannot be said that there is; for in the paragraph which has been quoted Hansen explicitly states that the coefficient of the term $(8g''-13g')$ is insensible *unless* there be included the terms depending on the product of the first power of the disturbing force of *Venus* with the *square* and *cube* of the disturbing force of the Sun. *But Delaunay has entirely omitted the terms of this order in his investigation.* Delaunay himself does not seem to have noticed this discrepancy; partly because he seems to call the first power of the disturbing force of *Venus*, also the first power of the disturbing force of the Sun. And his investigation being performed with the aid of his new and elegant method of attacking the lunar theory, in this portion they are not easily followed by anyone not perfectly familiar with this most laborious method. Had this not been so, it is probable that attention would have been directed before now to this discrepancy.

"There is little difficulty in ascertaining what probably were Delaunay's reasons for omitting these terms. It is obvious that the terms neglected will be smaller than those which he has retained, and which depend upon the first power of the disturbing force of the Sun. But these last are very small, so that there could be no valid reason for including the others which were still smaller. Delaunay, therefore, was perfectly justified in omitting these terms. But this very circumstance is enough to suggest the inquiry whether Hansen was really referring to these terms, or whether in his remarks he does not refer to some entirely distinct class of terms whose existence has been overlooked by Delaunay. Is there, then, a second class of terms to which Hansen's remarks may really apply?"

In my Paper I then proceed to show that on developing the differential equations in the ordinary manner, there do arise a class of terms which correspond exactly with Hansen's description, namely the terms which express the direct action of the Sun upon the perturbations in the motion of the Moon which are produced by the direct action of the planet; and show, further, that it is to these terms, and these only, to which Hansen could have referred in the paragraph already quoted, as

the portion of his investigation from which he obtained the large value of the coefficient with the argument $(8g''-13g')$. As it seemed certain that Delaunay had entirely neglected these terms, in this difference appeared the origin of the discrepancy between the results obtained by the two investigators.

The evidence thus adduced seemed to me to be conclusive, so I have on several occasions referred to this Paper of mine as establishing the incompleteness of Delaunay's evaluation of these terms. Moreover, I have since verified the opinion that it was to these terms that Hansen refers, by proving, by the actual development of the equations, that Hansen's method does lead to the formation of these terms, and that they do render sensible the coefficient of this *Venus* term.

Lately there has appeared good reason for believing that this evidence is not deemed by others to be nearly so conclusive as it appears to me, and that more than one distinguished astronomer remained unconvinced of the insufficiency of this method of Delaunay's.

Moreover, of late, Delaunay's method of calculating terms of long period has been applied by other astronomers to the determination of the values of further terms of this kind, only with the result of finding the same discrepancy between the values so obtained and those yielded by other methods. In each case the value obtained by following Delaunay's method, which may be called the method of transformed elements, yields only a small fraction of the result obtained by the methods of perturbed polar co-ordinates or of the direct variation of elliptic elements. Thus, the discrepancy to which Prof. Adams and Mr. Hind, as well as Prof. Newcomb, have directed attention, between the results obtained by M. Gogou for the term due to the action of *Mars* with the argument $(l-24l''+20l''')$, and by Prof. G. W. Hill for the Jovian Perigee term with the argument $(2\theta_{iv}-2\alpha)$, and those previously obtained by myself by the method of perturbed co-ordinates, forms merely an exact repetition of the discordance between the values for the *Venus* term $(8l'-13l'')$ found by Prof. Hansen and M. Delaunay by the same difference of method.

The question involved, therefore, is clearly not a mere difference in computation, such as might be ascribed to some oversight or error, but is a fundamental difference in principle between the results derived from the method of transformed elements, as applied to these terms by M. Delaunay, M. Gogou, and Prof. Hill, and the results of the methods of perturbed co-ordinates or perturbed elliptic elements as employed by Prof. Hansen and myself.

This statement places the matter on a clear footing; it remains to trace to its source this fundamental difference in principle between the two results.

I would place the question in this form. *Does the method employed by M. Delaunay yield the complete value of these coefficients?*

With Hansen, I say, No!

Let me clearly define the exact nature of my dissent from the method employed by Delaunay for the investigation of these terms of long period. I do not question the principle on which it is founded. I admit as freely as I admire the beautiful simplicity of the principle on which Delaunay has founded his development of the Lunar Theory. I admit the accuracy of the results embodied in the two great volumes forming tomes xxviii and xxix of the *Mémoires de l'Académie des Sciences.* As there applied it yields perfect results. My contention is that, in applying this method to the calculation of the perturbations produced by the disturbing action of the planets, he has omitted to consider a portion of the complete disturbing function which must be taken into consideration in order to obtain the complete value of these perturbations.

Consider first the development of the disturbing function which is to serve as the basis of the investigation.

Let R denote the disturbing function when the elements of the orbit of the Moon have their instantaneous elliptic values denoted by

$$\mathrm{x\ y\ z\quad X\ Y\ Z.}$$

Further, let the general term of R be denoted by

$$\mathrm{R}\cos \mathrm{w} = (\Lambda)\, e^{\mathrm{Fx}+\mathrm{Gy}+\mathrm{Hz}} \cdot \cos\{(\lambda)+f\mathrm{X}+g\mathrm{Y}+h\mathrm{Z}\} \qquad (1)$$

where (Λ) and (λ) are supposed to be independent of the elements of the disturbed orbit, and to be absolutely constant, therefore, as far as concerns any variations in these elements.

Suppose R to denote the value of R, when the elements of the disturbed orbit have their constant mean values, so that R will be the same function of the mean elements denoted by

$$x\ y\ z\quad X\ Y\ Z,$$

as R is of the instantaneous elements

$$\mathrm{x\ y\ z\quad X\ Y\ Z.}$$

Hence the general term of R may be written in the form

$$R\cos\omega = (\Lambda)\, e^{Fx+Gy+Hz} \cdot \cos\{(\lambda)+fX+gY+hZ\} \qquad (2)$$

Let each element of the orbit be regarded as the sum of the mean constant value, and of a series of periodical functions which collectively represent the periodical perturbations of the element, so that, for instance,

$$\mathrm{X} = x+\delta x = x+\delta_1 x+\delta_2 x+\delta_3 x+\ \ldots\ = x+\Sigma\,\delta_m x \qquad (3)$$

Then R is to be developed in terms of R, and of these variables which represent the periodical perturbations in the elements of the disturbed orbit.

Let u be taken as the general representative of the similar

elements which have been denoted by x y z, and let I be taken for the general representative of the corresponding coefficients F G H. Similarly, let U be supposed to represent the similar elements which have been denoted by X Y Z, and i to represent the corresponding coefficients $f\,g\,h$. Further, suppose

$$\begin{aligned} \mathrm{u} &= u + \delta u \quad = u + \Sigma\delta_m u \\ \mathrm{U} &= U + \delta U \quad = U + \Sigma\delta_m U \end{aligned} \tag{4}$$

where, as before, δu δU represent the periodic perturbations of the elements whose mean constant values are denoted by u U.

To effect the desired development, assume that

$$\begin{aligned} \delta_m u &= \Sigma j^m . \frac{\mathrm{I}}{\omega} . R^m \cos\omega \\ \delta_m U &= \Sigma J^m . \frac{\mathrm{I}}{\omega} . R^m \sin\omega \end{aligned} \tag{5}$$

where on the right-hand side the affix m indicates the number of accents to be attached to the letters j J R.

Next, by successive differentiation

$$\begin{aligned} \frac{d^s R}{d u^s} &= \Sigma I^s R \cos\omega \\ \frac{d^s R}{d U^s} &= \Sigma i^s \left\{ \cos s\frac{\pi}{2} . R\cos\omega - \sin s\frac{\pi}{2} . R\sin\omega \right\} \end{aligned} \tag{6}$$

Put

$$\mathrm{D}_u = \delta u . \frac{d}{d u}$$

$$\mathrm{D}_U = \delta U . \frac{d}{d U}$$

then

$$\begin{aligned} \mathrm{R} = R + \delta R &= \{\epsilon^{\Sigma(\mathrm{D}_u + \mathrm{D}_U)}\} R \\ &= \{\Sigma(1 + \mathrm{D}_u + \tfrac{1}{2}[\mathrm{D}_u]^2 + \ldots .)(1 + \mathrm{D}_U + \tfrac{1}{1\cdot 2}[\mathrm{D}_U]^2 + \ldots .)\} R \end{aligned} \tag{7}$$

For conciseness put

$$\begin{aligned} [R_s^m \quad (I_r j_s^m)\frac{\mathrm{I}}{\omega_s}]^k &= (I_r)^k (j_{s_1}^m R_{s_1}^m \frac{\mathrm{I}}{\omega_{s_1}} + \ldots . + j_{s_k}^m R_{s_k}^m \frac{\mathrm{I}}{\omega_{s_k}})^k \\ [R_s^m (q\, i_r\, J_s^m)\frac{\mathrm{I}}{\omega_s}]^k &= (q' q'' \ldots q^k)(i_r)^k (J_{s_1}^m R_{s_1}^m \frac{\mathrm{I}}{\omega_{s_1}} + \ldots . + J_{s_k}^m R_{s_k}^m \frac{\mathrm{I}}{\omega_{s_k}})^k \end{aligned} \tag{8}$$

and further, let Σ_m denote a summation with regard to the affix m, so that, for example,

$$\begin{aligned} [\Sigma_m R_s^m (I_r j_s^m)\frac{\mathrm{I}}{\omega_s}]^k = (I_r)^k \{ &[j'_{s_1} R'_{s_1} + \ldots . + j''_{s_1} R''_{s_1} + \ldots .]\frac{\mathrm{I}}{\omega_{s_1}} + \\ &\ldots . + [j_{s_k} R_{s_k} + \ldots . + j_{s_k}^m R_{s_k}^m + \ldots .]\frac{\mathrm{I}}{\omega_{s_k}} \}^k \end{aligned} \tag{9}$$

In these expressions the suffixes $r, s\, s_1\, s_2 \ldots s_k$ are supposed to be numbers employed to distinguish different coefficients of the classes $R\, I\, i\, J\, j \ldots$ belonging to an argument. Thus each of these classes of co-efficient belonging to an argument ω_{s_k} distinguished from other arguments by carrying the subscript number denoted by $_{s_k}$, will be distinguished from other similar coefficients by being written in the form

$$R_{s_k} . I_{s_k}\, i_{s_k}\, J_{s_k}\, j_{s_k} \ldots .$$

Let the prefix Σ_u attached to any function of the general coefficients $I\, i \ldots$ indicate that they take in succession every value included under the general term, so that, for example,

$$\Sigma_u (I_{s_1} i_{s_2} - q\, i_{s_1} I_{s_2}) e^{-u} = (F_{s_1} f_{s_2} - q\, f_{s_1} F_{s_2}) e^{-x} + (G_{s_1} g_{s_2} - q\, g_{s_1} G_{s_2}) e^{-y} + (H_{s_1} h_{s_2} - q\, h_{s_1} H_{s_2}) e^{-z} \qquad (10$$

If, however, this sign be not prefixed, then it is to be understood that the coefficient takes only the particular value corresponding to the particular value assigned to u. Thus, in the general expression for the perturbations of u, suppose u to represent x, then

$$(I_{s_1} i_{s_2} - q\, i_{s_1} I_{s_2}) e^{-u} = (F_{s_1} f_{s_2} - q f_{s_1} F_{s_2}) e^{-x}$$

These conventions have been introduced solely for the purpose of conciseness, as they obviate the necessity of writing out all the coefficients.

From the values assigned to the symbol D the following expressions can be derived :—

$$[\mathrm{D}_u]^k R \cos\omega = \left\{ \tfrac{1}{2} \Sigma_m R_s^m [\Sigma_u (I_r j_s^m)] \frac{1}{\omega_s} \right\}^k \cos(\omega_r + q'\omega_{s_1} + q''\omega_{s_2} + \ldots + q^k \omega_{s_k})$$

$$[\mathrm{D}_U]^k R \cos\omega = \left\{ \tfrac{1}{2} \Sigma_m R_s^m [\Sigma_u (q\, i_r J_s^m)] \frac{1}{\omega_s} \right\}^k \cos(\omega_r + q'\omega_{s_1} + q''\omega_{s_2} + \ldots + q^k \omega_{s_k})$$

Hence

$$\{[\mathrm{D}_u]^{k'} [\mathrm{D}_U]^{k''}\} R \cos\omega = \left\{ \tfrac{1}{2} \Sigma_m R_s^m [\Sigma_u (I_r j_s^m)] \frac{1}{\omega_s} \right\}^{k'} \times \left\{ \tfrac{1}{2} \Sigma_m R_s^m [\Sigma_u (q\, i J_s^m)] \frac{1}{\omega_s} \right\}^{k''} \cos(\omega_r + q'\omega_{s_1} + q''\omega_{s_2} + \ldots + q^{k'+k''} \omega_{s_{k'+k''}})$$

In these expressions the coefficients $q'\ q''\ q''' \ldots$ only take the values plus or minus unity, and have been introduced for the purpose of more clearly showing the changes which occur in the coefficients where changes are introduced into the arguments. Thus, by giving in succession the values plus or minus unity to the coefficients $q'\ q''\ q''' \ldots q^k$ in the argument denoted by

$$\omega = \omega_r + q'\omega_{s_1} + q''\omega_{s_2} + \ldots + q^k \omega_{s_k}$$

it will take in succession every value which can arise from the combination of the argument $\omega_{s_1} \ldots \omega_{s_k}$ with the argument ω_r, and by giving the same values to $q' \ldots q_k$ in the preceding expressions for the coefficients attached to this argument, there will be obtained the correct value of the corresponding coefficients.

By substituting these values of the functions denoted by the symbol D in the expression for R there will be obtained the complete development of the general term of the disturbing function in the form

$$\begin{aligned} \mathrm{R}\cos \mathrm{w} = R\cos\omega + & \left\{\tfrac{1}{2}\Sigma_m R^m_{s_1}[\Sigma_u(I_r j^m_{s_1} + q\, i_r J^m_{s_1})]\,\frac{\mathrm{I}}{\omega_{s_1}}\right\} R_r \cos(\omega_r + q'\omega_{s_1}) \\ & + \ldots\ldots \\ & + \frac{\mathrm{I}}{k}\left\{\tfrac{1}{2}\Sigma_m R^m_{s}[\Sigma_u(I_r j^m_{s} + q' i_r J^m_{s})]\,\frac{\mathrm{I}}{\omega_{s}}\right\}^k R_r \cos(\omega_r + \Sigma^k q\omega_s) \\ & + \ldots\ldots \end{aligned} \tag{12}$$

This expression will give, in turn, the complete development of R in terms of R and the periodical perturbations.

It remains to obtain R in an explicit form.

Let ρ denote the geocentric distance of the disturbing body; H denote the geocentric angular distance between the disturbing body and the Moon; and rVλ denote the geocentric radius vector, true longitude and latitude of the Moon in its disturbed orbit. Then, putting M for the mass of the disturbing body, the function which expresses its disturbing action on the Moon will be

$$\mathrm{R} = \mathrm{M}\left\{\frac{r^2}{\rho^3}\left(\tfrac{3}{2}\cos^2\mathrm{H} - \tfrac{1}{2}\right) + \ldots\ldots\right\} \tag{13}$$

Suppose the disturbing body to be a planet moving in an orbit so slightly inclined to the ecliptic that its latitude may be regarded as insensible. Put $r_1 V_1$ for the heliocentric radius vector and longitude of the planet, and r_0 V_0 for the heliocentric radius vector and longitude of the Earth; then, as

$$\begin{aligned} \rho^2 &= r_1^2 + r_0^2 - 2r_1 r_0 \cos(V_1 - V_0) \\ \cos\mathrm{H} &= \cos\lambda\left\{\frac{r_1}{\rho}\cos(\mathrm{V} - V_1) - \frac{r_0}{\rho}\cos(\mathrm{V} - V_0)\right\} \end{aligned}$$

the disturbing function expressing the direct action of a planet upon the Moon may be written as

$$\begin{aligned} \mathrm{R}_1 = \mathrm{M}_1\Big\{ & \tfrac{1}{4}\cdot\frac{r^2}{\rho^3}(1 - 3\sin^2\lambda) + \tfrac{3}{4}\cdot\frac{r^2}{\rho^5}(1 - \sin^2\lambda)[r_1^2\cos(2\mathrm{V} - 2V_1) \\ & + r_0^2\cos(2\mathrm{V} - 2V_0) + 2r_1 r_0\cos(2\mathrm{V} - V_1 - V^0)] + \ldots\ldots\Big\} \end{aligned}$$

The ordinary disturbing function of the lunar theory which represents the direct disturbing action of the Sun can be obtained

from the preceding by making r_1 equal to zero. It can be written, therefore, as

$$R_0 = M_0 \left\{ \tfrac{1}{4} \cdot \frac{r^2}{r_0^3} (1 - 3\sin^2\lambda) + \tfrac{3}{4} \cdot \frac{r^2}{r_0^3} (1 - \sin^2\lambda) \cos(2V - 2V_0) + \dots \right\} \quad (14)$$

These form the quantities to be developed in the manner already indicated.

Suppose the method of investigation adopted be that of perturbed co-ordinates, similar to that employed in my general method of treating the lunar theory (*Memoirs*, vol. xliv. 1878), so that R is to be developed in terms of the elliptic co-ordinates and their perturbations.

To simplify the expressions, suppose the minor effects arising from the perturbations in the latitude of the Moon to be disregarded, so that the perturbed co-ordinates of the Moon may be supposed reduced to the radius vector and longitude.

Further, let

v = logarithm of the radius vector of the disturbed orbit.

V = the longitude in the disturbed orbit.

And suppose

$$\begin{aligned}
&\Lambda_1 = \tfrac{1}{4} \cdot M_0 \cdot \frac{1}{r_0^3} && \lambda_1 = 0 \\
&\Lambda_2 = \tfrac{3}{4} \cdot M_0 \cdot \frac{1}{r_0^3} && \lambda_2 = -2V_0 \\
&\Lambda_3 = \tfrac{1}{4} \quad M_1 \cdot \frac{1}{\rho^3} && \lambda_3 = 0 \\
&\Lambda_4 = \tfrac{3}{4} \quad M_1 \cdot \frac{1}{\rho^3} \cdot \frac{r_1^2}{\rho^2} && \lambda_4 = -2V_1 \\
&\Lambda_5 = \tfrac{3}{4} \quad M_1 \cdot \frac{1}{\rho^3} \cdot \frac{r_0^2}{\rho^2} && \lambda_5 = -2V_0 \\
&\Lambda_6 = -\tfrac{3}{4} \quad M_1 \cdot \frac{1}{\rho^3} \cdot \frac{2r_1 r_0}{\rho^2} && \lambda_6 = -V_1 - V_0
\end{aligned} \quad (15)$$

Then the preceding expressions for the disturbing function reduce to

$$\begin{aligned}
R_0 &= (\Lambda_1)e^{2v} \cos\{(\lambda_1)\} + (\Lambda_2)e^{2v} \cos\{(\lambda_2) + 2V\} + \dots \\
R_1 &= (\Lambda_3)e^{2v} \cos\{(\lambda_3)\} + (\Lambda_4)e^{2v} \cos\{(\lambda_4) + 2V\} + (\Lambda_5)e^{2v} \cos\{(\lambda_5) + 2V\} \\
&\quad + (\Lambda_6)e^{2v} \cos\{(\lambda_6) + 2V\} + \dots
\end{aligned} \quad (16)$$

Each of these is merely a particular case of the general form (2), and can be developed in the manner already indicated.

For the present let the subscript $_0$ be employed to denote quantities introduced through the disturbing action of the Sun, and the subscript $_1$ to denote quantities introduced through the disturbing action of the planet. Further, as before, suppose R to denote the value of the disturbing function R when the lunar co-ordinates have their undisturbed values. Then it is known

that R can be developed in a series of cosines with arguments which are explicit functions of the time. It may be assumed, therefore, that

$$R = R_0 + R_1 = \Sigma R_0 \cos \beta_0 + \Sigma R_1 \cos \beta_1 = \Sigma R \cos \beta \qquad (17)$$

Let the elliptic values of r v V be denoted by $r\ v\ V$, and suppose the perturbations of these to be expressed in the forms

$$\begin{aligned} \delta v &= \Sigma a_0^m \cos \alpha_0 + \Sigma a_1^m \cos \alpha_1 \\ \delta V &= \Sigma b_0^m \sin \alpha_0 + \Sigma b_1^m \sin \alpha_1 \end{aligned} \qquad (18)$$

Then the above give the values of the general symbols $Ii\,Jj\,\frac{I}{\omega}$, which enter into the expression (12) for the development of the general term of the disturbing function.

Employing the values given above, it is easy to transform the complete development of the disturbing function into the following form, where quantities depending on the square and cube of the disturbing force of the planet have not been written down.

$$\begin{aligned} \mathrm{R} = \quad & \Sigma\, . R_0 A_0^q \cos (\beta_0 + q\alpha_0) \\ & + \Sigma\ R_1 A_0^q \cos (\beta_1 + q\alpha_0) \\ & + \Sigma\ R_0 A_0^q [a_1 + q_1 b_1] \cos (\beta_0 + q\alpha_0 + q_1 \alpha_1) \end{aligned} \qquad (19)$$

where, for convenience, the entire perturbations of the Sun with any given argument have been summed in the form

$$A_0^q \cos \alpha_0 = \{1 + [a_0 + q b_0] + \tfrac{1}{2}[a_0 + q b_0]^2 + \ldots\ldots\} \cos \alpha_0$$

A certain amount of interpretation is involved in the expression for the disturbing function written in the preceding highly condensed form, thus the quantities b_0 become zero for every term whose argument β is explicitly independent of V or of l, the Moon's mean longitude. But for the present purpose this is immaterial, as all three terms of (19) are to be identically interpreted, and when required the need for this interpretation can be obviated by writing each term in a somewhat more extended form.

The preceding expression for R consists of three terms: the first yields the ordinary lunar perturbations depending purely on the disturbing force of the Sun; the second yields the ordinary perturbations due to the direct action of the planet; and the third yields the indirect planetary perturbations in the motion of the Moon due to the action of the Sun on the perturbations introduced into the lunar motions by the direct action of the planet. These may here be termed the perturbations of Classes I., II., and III.

It only remains to substitute this value of the disturbing function in the ordinary differential equations to the lunar coordinates, to enable the perturbations produced by the disturb-

ing action of the planet to be determined with the same exactitude as the ordinary perturbations due to the disturbing action of the Sun.

It is in this manner that I first calculated the value of these perturbations with arguments of long period.

But it is possible to treat the preceding disturbing function under its general form (12) in another and more direct way, that is by the method of disturbed elements. The quantities

$$x\ y\ z \qquad X\ Y\ Z$$

have not been defined, beyond by the conditions implied in the form assigned to the general term (1) of R.

These quantities may be conveniently defined so that they lead to a canonical system of differential equations of the form

$$\begin{aligned} \frac{du'}{dt} &= -\frac{dR}{dU'} \\ \frac{dU'}{dt'} &= -\frac{dR}{du'} \end{aligned} \tag{20}$$

but they may be still more symmetrically employed by slightly departing from the preceding form, and defining them by the condition

$$\begin{aligned} \frac{du}{dt} &= \epsilon^{-u}\frac{dR}{dU} = -\epsilon^{-u}\Sigma iR \sin w \\ \frac{dU}{dt} &= -\epsilon^{-u}\frac{dR}{du} = -\epsilon^{-u}\Sigma IR \cos w \end{aligned} \tag{21}$$

where the system of elements is such that the three elements typified by u are simple exponential functions of the three elliptic constants, the mean distance, eccentricity, and sine of semi-inclination; and the three elements typified by U represent the three semi-periodic elliptic elements, the mean longitude, longitude of perigee, and longitude of node.

The differential equations depend, therefore, merely on particular cases of the general development (12) of the general term (1). Hence, substituting and integrating

$$\begin{aligned} u = u + \epsilon^{-u}\Sigma \Big\{ & \frac{i_{s_0}}{\omega_{s_0}} R_{s_0} \cos \omega_{s_0} + \ldots . \\ & + \frac{i_{s_0}}{\omega_{s_0} + \Sigma_1^k q\omega_s} \cdot \frac{1}{k} \cdot \left\{ \tfrac{1}{2}\Sigma_m R_s^m [\Sigma_u (I_{s_0} j_s^m - q i_{s_0} J_s^m) \frac{1}{\omega_s}] \right\}^k R_{s_0} \\ & \cos (\omega_{s_0} + \Sigma_1^k q\omega_s) + \ldots . \Big\} \\ U = U - \epsilon^{-u}\Sigma \Big\{ & \frac{I_{s_0}}{\omega_{s_0}} R_{s_0} \sin \omega_{s_0} + \ldots . \\ & + \frac{I_{s_0}}{\omega_{s_0} + \Sigma_1^k q\omega_s} \cdot \frac{1}{k} \cdot \left\{ \tfrac{1}{2}\Sigma_u R_s^m [\Sigma_u (I_{s_0} j_s^u - q i_{s_0} J_s^u) \frac{1}{\omega_s}] \right\} R_{s_0} \\ & \sin (\omega_{s_0} + \Sigma_1^k q\omega_s) + \ldots . \Big\} \end{aligned} \tag{22}$$

These expressions form the complete value of the perturbed or instantaneous elements, and are rigidly correct to any determined order of accuracy. To form the coefficient of the kth term it is only necessary to give the arguments

$$\omega_{s_0} \quad \omega_{s_1} \quad \omega_{s_2} \quad \cdots \quad \omega_{s_k}$$

every value which exists in the disturbing function R. To form the complete value of the perturbations with any given argument ω_p, it is only necessary to give to $s_0\, s_1 \ldots s_k$ every value consistent with the condition

$$\omega_{s_0} + q'\omega_{s_1} + q''\omega_{s_2} + \cdots + q^k\omega_{s_k} = \omega_p$$

There exists no difficulty in determining these conditions, and thus calculating the perturbation of any given form to any desired accuracy.

It remains to apply these results to the investigation of the perturbations of Class III., or those due to the indirect effect of the disturbing action of a planet. The problem may be stated thus:—Suppose the disturbing action of a planet to add an additional term to the perturbations of the elements of the lunar orbit, and suppose this additional term to have so small a coefficient that its square may be neglected from its exceeding smallness. Then the existence of this new term will alter the normal disturbing action of the Sun, and in this manner give rise to a series of additional perturbations. It is required to determine them.

Let this additional term which is supposed added to each of the disturbed elements be denoted by

$$\begin{aligned} \delta_1 u &= a_u \cos\zeta \\ \delta_1 U &= A_u \sin\zeta \end{aligned} \tag{23}$$

Suppose the preceding additional quantities introduced into the expression for the general term of R; as the square and product of these variations are to be neglected, the additional terms which will arise may be written in the form

$$\begin{aligned} \delta_1 \mathrm{R} &= \Sigma\tfrac{1}{2}\{\Sigma_u(I\,a + q\,i\,A)\}\mathrm{R}\cos(\zeta + q\mathrm{w}) \\ &= \Sigma\phi(\mathrm{A})\,.\,\mathrm{R}\cos(\zeta + q\mathrm{w}) \end{aligned} \tag{24}$$

where, as the function denoted by the symbol ϕ (A) involves only perturbations, it may be regarded as constant in developing R and w.

Substitute in the differential equations, they become

$$\begin{aligned} \frac{\mathrm{d}\,.\,\delta u}{dt} &= -e^{-u}\Sigma\,.\,i\,.\,\phi(\mathrm{A})\,.\,\mathrm{R}\sin(\zeta + q\mathrm{w}) \\ \frac{\mathrm{d}\,.\,\delta U}{dt} &= -e^{-u}\Sigma\,.\,I\,.\,\phi(\mathrm{A})\,.\,\mathrm{R}\cos(\zeta + q\mathrm{w}) \end{aligned} \tag{25}$$

These are particular cases of the general form (21), and can be

developed and integrated in exactly the same manner, yielding perfectly analogous expressions for the additional perturbations produced in the values of the elements u and U. The general term for these additional perturbations may be written

$$\delta u = +\epsilon^{-u}[\phi(A) - a_u] \cdot \frac{1}{k} \cdot \left\{\tfrac{1}{2}\Sigma_m R_s^m [\Sigma_u (I_{s_0} j_s^m - q q^k i_{s_0} J_s^m)] \frac{1}{\omega_s}\right\}^k \cdot$$

$$\frac{q\, i_{s_0} R_{s_0}}{\zeta + q\omega_{s_0} + \Sigma_1^k q\omega_s} \cos(\zeta + q\omega_{s_0} + \Sigma_1^k q\omega_s) \qquad (26)$$

$$\delta U = -\epsilon^{-u}[\phi(A) - a_u] \cdot \frac{1}{k} \cdot \left\{\tfrac{1}{2}\Sigma_m R_s^m [\Sigma_u (I_{s_0} j_s^m - q q^k i_{s_0} J_s^m)] \frac{1}{\omega_s}\right\}^k \cdot$$

$$\frac{I_{s_0} R_{s_0}}{\zeta + q\omega_{s_0} + \Sigma_1^k q\omega_s} \sin(\zeta + q\omega_{s_0} + \Sigma_1^k q\omega_s)$$

This is the second form in which I have calculated the values of these terms of long period due to the disturbing action of the planet.

There is now to be considered the form under which the preceding methods lead to the values for a term of long period due to the disturbing action of a planet.

Returning to the first method, let the direct disturbing action of a planet give rise to a term of long period of the form

$$B \sin \zeta$$

It is known that the value of the ordinary disturbing function involves every argument which exists in the ordinary perturbations of the Moon arising from the disturbing action of the Sun. Hence the series of arguments in the expression (19) denoted by $(\beta_0 + q\alpha_0)$, representing the arguments comprised in the complete value of the ordinary disturbing function, is identical with the series of arguments denoted by α_0, which represent the corresponding perturbations in the lunar co-ordinates. If, then, the argument of long period be

$$\zeta = \zeta_1 + \zeta_0$$

where by ζ_1 is denoted the portion of the complete argument more directly introduced through the co-ordinates of the planet, and by ζ_0 is denoted the portion more directly introduced through the co-ordinates of the Moon, it is evident, from the similarity in form of R_1 and R_0, that the portion ζ_0 must be identical with one of the arguments comprised in the series β_0 in (17), or with one of the arguments of the ordinary perturbations comprised in the series α_0. As the series of arguments α_1 comprises every argument in the entire series of perturbations produced by the planet, it will comprise every argument in the series $(\beta_1 + q\alpha_0)$; and no others, as the series denoted by $(\beta_0 + q\alpha_0)$ is identical with that denoted by α_0. Hence every term in the perturbations due to the action of the planet must appear in the series $(\beta_1 + q\alpha_0)$.

Consequently, the argument ζ must be one of the arguments comprised in the second term of (19) in the form $(\beta_1 + q a_0)$.

The second term of (19)

$$\Sigma R_1 A_0^q \cos(\beta_1 + q a_0) \tag{27}$$

represents the disturbing function resulting from substituting in the value of R_1 the complete value of the co-ordinates of the Moon as perturbed by the disturbing action of the Sun. Hence, if

$$(R_1 A_0^q)_\zeta \cdot \cos \zeta \tag{28}$$

denote the complete portion of this expression depending on the argument of long period ζ, it will give the complete value of this term as explicitly depending on the direct disturbing function R_1.

There are two methods by which from this term there can be derived the value of the term forming the perturbations with this argument in the Moon's longitude, which has been denoted by B sin ζ, or in other words, by which B can be evaluated.

The first is by substituting this and certain other associated terms in the ordinary differential equations given in my memoir on a "General Method of Treating the Lunar Theory" (*Memoirs*, vol. xliv. 1878), when the final equation to B will be obtained in the form

$$\frac{d}{dt} \cdot \mathrm{B} \sin \zeta = \{ \phi(R_1 A_0) \cdot \} \cos \zeta \tag{29}$$

where the coefficient on the right-hand side is a function depending mainly on the coefficient of the terms with the arguments ζ and $\zeta \pm a$ in the value of the complete disturbing function. Hence ζ becomes the integrating factor, and from the equation

$$\zeta \mathrm{B} = \phi(R_1 A_0) \tag{30}$$

there is derived the value

$$\mathrm{B} = \frac{1}{\zeta} \cdot \phi(R_1 A_0) \tag{31}$$

The other method is equivalent to that adopted by Delaunay in his investigation of the terms of long period arising from *Venus* (*Conn. des Temps*, App., 1862 and 1863). He substitutes the preceding value for the term in the disturbing function with the argument ζ in the differential equation

$$\frac{d\,l}{dt} = -\frac{2}{an} \cdot \frac{d\mathrm{R}}{da} + \frac{e}{2a^2 n} \cdot \frac{d\mathrm{R}}{de} \tag{32}$$

and integrates (*Conn. des Temps*, 1863. Add. p. 41).

In this manner

$$\frac{d}{dt} \cdot \mathrm{B}' \sin \zeta = \phi'(R_1 A_0^q)_\zeta \cos \zeta \tag{33}$$

where the coefficient on the right-hand side is a simple function of the coefficient of the argument ζ in the disturbing function as developed above. Hence, as before, the integrating factor is ζ, and

$$\zeta B' = \phi'(R_1 A_0^q)_t \tag{34}$$

or

$$B' = \frac{1}{\zeta}\phi'(R_1 A_0^q)_t \tag{35}$$

The coefficient B′ thus determined is not exactly the same as B previously found; as B′ is the coefficient of the term of this form in the mean longitude, whilst B is the coefficient of the term in the true longitude. The two, however, only differ by small quantities, unimportant for the present purpose.

Subsequently it will be shown that this last result, or the value B′, is the result which Delaunay obtained for the value of the coefficient of the terms of long period arising from the disturbing action of *Venus*.

In reality, however, neither of these equations, (30) or (34), is complete.

This can be shown as follows.

When the values of B or B′ resulting from the previous equations (30) and (34), and forming what is really only a first approximation to the complete value, come to be substituted in the complete disturbing function, they give rise to the terms included in the third portion of the disturbing function as developed in (19). This portion may be written somewhat more in detail under the form

$$\begin{aligned}&\Sigma\{R_0[a_1 + q_1 b_1]\cos(\beta_0 + q_1\alpha_1)\\ &+ R_0[a_1 + q_1 b_1][a_0 + q b_0]\cos(\beta_0 + q\alpha_0 + q_1\alpha_1)\\ &+ \tfrac{1}{2}R_0[a_1 + q_1 b_1][a_0 + q b_0][a_0' + q' b_0']\cos(\beta_0 + q\alpha_0 + q'\alpha_0' + q_1\alpha_1)\\ &+ \ldots\ldots\end{aligned} \tag{36}$$

Now the series of coefficients denoted by b_1, being the series of coefficients of the perturbations in longitude due to the disturbing action of the planet, they will contain the coefficient B, and thus give rise to the series of terms

$$\begin{aligned}\Sigma.\, R_0[q_1 B]\{&\cos(\beta_0 + q_1\zeta)\\ &+ [a_0 + q b_0]\cos(\beta_0 + q\alpha_0 + q_1\zeta)\\ &+ [a_0 + q b_0][a_0' + q' b_0']\cos(\beta_0 + q\alpha_0 + q'\alpha_0' + q_1\zeta)\\ &+ \ldots\ldots\end{aligned} \tag{37}$$

Then this series of terms will not disappear from the value of either

$$\frac{dR}{da}$$

or

$$\frac{dR}{dl}$$

as the argument β_0 will involve l, and R_0 will involve a, and in forming these differentials a_0 b_0 a_0 are to be regarded as constants.

Now β_0 and α_0 represent the same series of arguments, so for each argument in the series β_0 there will be an identically similar argument in the series α_0. Hence one of the pairs of arguments denoted by

$$\beta_0 + q\alpha_0$$

will vanish in each case, and reduce the second term of (37) to the form

$$R_0[q_1 B]\{[a_0 + qb_0]\}\cos(q_1\zeta) \tag{38}$$

As a_0 and b_0 will not be equal, it follows that this coefficient cannot vanish whichever sign be given to q.

As R_0 a_0 b_0 are all functions of one or more of the small quantities commonly denoted by m, e, ... η, and of the second order at least, the above term may be written in the form

$$\{\chi_1(m \ldots .)^4 + \chi_1'(m \ldots .)^5 + \ldots .\}[B]\cos\zeta. \tag{39}$$

Similarly, there will be a number of combinations of the arguments of the series β_0 α_0 α_0' which will make

$$\beta_0 + q\alpha_0 + q'\alpha_0' = 0$$

and thus reduce the third term of the preceding value for this portion of the disturbing function to the form

$$R_0[q_1 B]\{\tfrac{1}{2}[a_0 + qb_0][a_0' + q'b_0']\}\cos(q_1\zeta) \tag{40}$$

or, as it may be written,

$$\{\chi_1''(m \ldots .)^6 + \ldots .\}[B]\cos\zeta. \tag{41}$$

The existence of these terms renders both of the equations (30) and (34) previously given for determining B and B′ incomplete. The first of them (30) should be written in the form

$$\zeta B = \phi(R_1 A_0) + \{\psi(m \ldots .)^4 + \psi_1(m \ldots .)^5 + \ldots .\}B$$

and the integrating factor instead of ζ is

$$\zeta - \{\psi(m \ldots .)^4 + \psi_1(m \ldots .)^5 + \ldots .\} \tag{42}$$

or

$$B = \frac{\phi(R_1 A_0)}{\zeta - \{\psi(m \ldots .)^4 + \psi_1(m \ldots .)^5 + \ldots .\}} \tag{43}$$

and the second of them (34) should be

$$\zeta B' = \phi'(R_1 A_0^q)_t + \{\psi(m \ldots .)^4 + \psi_1'(m \ldots .)^5 + \ldots .\}B \tag{44}$$

'ing factor instead of ζ is

$$\dots)^4 + \psi_1(m^3 \dots)^3 + \dots \} \tag{45}$$

$$\frac{\cdot'(R_1 A_0 q')_r}{\cdot'(m \dots)^3 + \dots \}} \tag{46}$$

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$$= q'[s_0 s_1]^m \tag{47}$$

to represent the development of R, the dis-
due to the direct action of the planet, it may be
form

$$\begin{aligned} &+ \Sigma.[R_1]_{s_0} \cdot \left\{ \frac{i_{s_0}}{w_{s_0}} \cos \omega_{s_0} + \dots + \frac{i_{s_0}}{\omega_{s_0} + \Sigma_1^k q \omega_s} \right. \\ &\qquad \left. \cdot \frac{I}{\lfloor \underline{k}} \{q'[s_0 s]^m\}^k \cos (\omega_{s_0} + \Sigma_1^k q \omega_s) + \dots \right\} \\ U = U - e^{-u} \Sigma.[R_1]_{s_0} &\left\{ \frac{I_{s_0}}{\omega_{s_0}} \sin \omega_{s_0} + \dots + \frac{I_{s_0}}{\omega_{s_0} + \Sigma_1^k q \omega_{s_0}} \right. \\ &\qquad \left. \cdot \frac{I}{\lfloor \underline{k}} \{q'[s_0 s]^m\}^k \sin (\omega_{s_0} + \Sigma_1^k q \omega_s) + \dots \right\} \end{aligned} \tag{48}$$

Then if ζ be the argument of a term of long period due to the disturbing action of the planet, these expressions will lead to the following values for the perturbations of the element:

$$\begin{aligned} a_u \cos \zeta &= + \frac{I}{\zeta} \cdot e^{-u} \cdot \left\{ i[R_1] + \dots + i_{s_0} \cdot \frac{I}{\lfloor \underline{k}} \frac{\partial^k}{\partial t^k} q^m \right\} + \dots \Big\} \cos \zeta \\ A_u \sin \zeta &= - \frac{I}{\zeta} \cdot e^{-u} \cdot \left\{ I[R_1] + \dots + I_{s_0} \cdot \frac{I}{\lfloor \underline{k}} \{q'[s_0 s]^m\}^k + \dots \right\} n \end{aligned} \tag{49}$$

with the condition that $s_0\ s_1 \dots s_k$ are to be given every value consistent with the condition that

$$[\omega_1]_{s_0} + q' \omega_{s_1} + q'' \omega_{s_2} + \dots + q^k \omega_{s_k} = \zeta$$

The argument ω_{s_0} has been written $[\omega_1]_{s_0}$ to show that it alone represents an argument derived from the series forming R, the remaining argument being derived from the expression for the ordinary perturbations produced by the Sun.

These values of the perturbations correspond to the values

as the argument β_0 will involve l, and R_0 will involve a, and in forming these differentials a_0 b_0 a_0 are to be regarded as constants.

Now β_0 and a_0 represent the same series of arguments, so for each argument in the series β_0 there will be an identically similar argument in the series a_0. Hence one of the pairs of arguments denoted by

$$\beta_0 + qa_0$$

will vanish in each case, and reduce the second term of (37) to the form

$$R_0[q_1\mathrm{B}]\{[a_0 + qb_0]\}\cos(q_1\zeta) \tag{38}$$

As a_0 and b_0 will not be equal, it follows that this coefficient cannot vanish whichever sign be given to q.

As R_0 a_0 b_0 are all functions of one or more of the small quantities commonly denoted by m, e, ... η, and of the second order at least, the above term may be written in the form

$$\{\chi_1(m \ldots .)^4 + \chi_1'(m \ldots .)^5 + \ldots .\}[\mathrm{B}]\cos\zeta. \tag{39}$$

Similarly, there will be a number of combinations of the arguments of the series β_0 a_0 a_0' which will make

$$\beta_0 + qa_0 + q'a_0' = 0$$

and thus reduce the third term of the preceding value for this portion of the disturbing function to the form

$$R_0[q_1\mathrm{B}]\{\tfrac{1}{2}[a_0 + qb_0][a_0' + q'b_0']\}\cos(q_1\zeta) \tag{40}$$

or, as it may be written,

$$\{\chi_1''(m \ldots .)^6 + \ldots .\}[\mathrm{B}]\cos\zeta. \tag{41}$$

The existence of these terms renders both of the equations (30) and (34) previously given for determining B and B′ incomplete. The first of them (30) should be written in the form

$$\zeta B = \phi(R_1 A_0) + \{\psi(m \ldots .)^4 + \psi_1(m \ldots .)^5 + \ldots .\}\mathrm{B}$$

and the integrating factor instead of ζ is

$$\zeta - \{\psi(m \ldots .)^4 + \psi_1(m \ldots .)^5 + \ldots .\} \tag{42}$$

or

$$\mathrm{B} = \frac{\phi(R_1 A_0)}{\zeta - \{\psi(m \ldots .)^4 + \psi_1(m \ldots .)^5 + \ldots .\}} \tag{43}$$

and the second of them (34) should be

$$\zeta \mathrm{B}' = \phi'(R_1 A_0^q)_t + \{\psi(m \ldots .)^4 + \psi_1'(m \ldots .)^5 + \ldots .\}\mathrm{B} \tag{44}$$

where the integrating factor instead of ζ is

$$\zeta - \{\psi'(m \ldots .)^1 + \psi_1'(m^2 \ldots .)^2 + \ldots .\} \tag{45}$$

or

$$B' = \frac{\phi'(R_1 A_0^q)_t}{\zeta - \{\psi'(m \ldots .)^1 + \psi_1'(m \ldots .)^2 + \ldots .\}} \tag{46}$$

These equations (43) and (46) represent the values found by myself, and, I have no doubt, by Hansen.

The second method of investigating these terms, or the method of perturbed elements, founded on equation (20) as developed in expressions (22) and (26), leads to exactly the same result. For still further brevity put

$$\Sigma_u (I_{s_0} j_{s_i}^m - qq' i_{s_0} J_{s_i}^m) \frac{I}{\omega_{s_1}} = q'[s_0 s_i]^m \tag{47}$$

then suppose (22) to represent the development of R, the disturbing function due to the direct action of the planet, it may be written in the form

$$\begin{aligned} u &= u + \epsilon^{-u} + \Sigma.[R_1]_{s_0} \cdot \left\{ \frac{i_{s_0}}{w_{s_0}} \cos \omega_{s_0} + \ldots \ldots + \frac{i_{s_0}}{\omega_{s_0} + \Sigma_i^k q\omega_s} \right. \\ &\qquad \left. \cdot \frac{I}{\lfloor \kappa} \{q'[s_0 s]^m\}^k \cos (\omega_{s_0} + \Sigma_i^k q\omega_s) + \ldots \ldots \right\} \\ U &= U - \epsilon^{-u} \Sigma.[R_1]_{s_0} \left\{ \frac{I_{s_0}}{\omega_{s_0}} \sin \omega_{s_0} + \ldots \ldots + \frac{I_{s_0}}{\omega_{s_0} + \Sigma_1^k q\omega_{s_0}} \right. \\ &\qquad \left. \cdot \frac{I}{\lfloor \kappa} \{q'[s_0 s]^m\}^k \sin (\omega_{s_0} + \Sigma_1^k q\omega_s) + \ldots \ldots \right\} \end{aligned} \tag{48}$$

Then if ζ be the argument of a term of long period due to the disturbing action of the planet, these expressions will lead to the following values for the perturbations of the element:

$$\begin{aligned} a_u \cos \zeta &= + \frac{I}{\zeta} \cdot \epsilon^{-u} \cdot \left\{ i[R_1] + \ldots \ldots + i_{s_0} \cdot \frac{I}{\lfloor \kappa} \sim t_q^m \right\} + \ldots \ldots \Big\} \cos \zeta \\ A_u \sin \zeta &= - \frac{I}{\zeta} \cdot \epsilon^{-u} \cdot \left\{ I[R_1] + \ldots \ldots + I_{s_0} \cdot \frac{I}{\lfloor \kappa} \{q'[s_0 s]^m\}^k + \ldots \ldots \right\} n \end{aligned} \tag{49}$$

with the condition that $s_0\ s_1 \ldots \ldots s_k$ are to be given every value consistent with the condition that

$$[\omega_1]_{s_0} + q'\omega_{s_1} + q''\omega_{s_2} + \ldots \ldots + q^k \omega_{s_k} = \zeta$$

The argument ω_{s_0} has been written $[\omega_1]_{s_0}$ to show that it alone represents an argument derived from the series forming R, the remaining argument being derived from the expression for the ordinary perturbations produced by the Sun.

These values of the perturbations correspond to the values

(30) and (34), and represent the direct action of the planet. They are equivalent to those given by Delaunay.

But it has already been shown that when these values come to be substituted in the disturbing function R_0 representing the direct action of the Sun, they give rise to the series of additional terms (26). The general term of these additional perturbations can be written in the form

$$\delta u = +\epsilon^{-u}[\phi(A)-a_u]\cdot\frac{1}{|k}\cdot\{q'[s_0 s]^m\}^k\frac{q\,i_{s_0}R_{s_0}}{\zeta+q\omega_{s_0}+\Sigma_1^k q\omega_s}\cos(\zeta+q\omega_{s_0}+\Sigma_1^k q\omega_s)$$
$$\delta U = -\epsilon^{-u}[\phi(A)-a_u]\cdot\frac{1}{|k}\cdot\{q'[s_0 s]^m\}^k\frac{I_{s_0}R_{s_0}}{\zeta+q\omega_{s_0}+\Sigma_1^k q\omega_s}\sin(\zeta+q\omega_{s_0}+\Sigma_1^k q\omega_s) \quad (50)$$

But the series of arguments by $\omega_s \ldots\ldots\ldots \omega_{sk}$ are identical, so that for a considerable number of combinations in the series there will hold the condition that

$$q\omega_{s_0}+q'\omega_{s_1}=0$$
$$\vdots \qquad\qquad \vdots$$
$$q\omega_{s_0}+\Sigma_1^k q\omega_s=0$$

whilst i_{s_0} and I_{s_0} do not vanish. Hence the above expressions will reduce to

$$a_u\cos\zeta = +\epsilon^{-u}[\phi(A)-a_u]\cdot\frac{1}{|k}\{q'[s_0 s]^m\}k.\ \frac{q\,i_{s_0}}{\zeta}\frac{R_{s_0}}{}\cdot\cos\zeta$$
$$A_u\sin\zeta = -\epsilon^{-u}[\phi(A)-a_u]\cdot\frac{1}{|k}\{q'[s_0 s]^m\}k.\ \frac{I_{s_0}}{\zeta}\frac{R_{s_0}}{}\sin\zeta \quad (51)$$

From (24), the right-hand side of this expression will involve both a_u and A_u, and R and $[s_0\, s]$ are each of the order $[m\ldots]^2$ at least, so that the preceding expression may be written in the form

$$\zeta a_u = \{\Psi[m\ldots.]^4+\Psi_1[m\ldots.]^5+\ldots.\}[a_u+f(\text{a.A.})]$$
$$\zeta A_u = \{\Psi'[m\ldots.]^4+\Psi'_1[m\ldots.]^5+\ldots.\}[A_u+f(\text{a.A})] \quad (52)$$

and the form of the integrating factors be

$$\zeta-\{\Psi[m\ldots.]^4+\Psi_1[m\ldots.]^5+\ldots.\} \quad (53)$$

the same as already found in (42) and (45).

The simplicity of the differential equations when the method of perturbed elements is employed in the preceding manner enables a further step to be made. By developing the function denoted by

$$\{q'[s_0 s]^m\}^k$$

it is possible to show that the terms involving the first of this series of functions will vanish from the preceding expression for the additional perturbations (51), as $q'[s_0 s_1]$ will be zero. Hence

there can be no term of the preceding kind in the longitude of the Moon which depends on the square of the disturbing force of the Sun, so that we have

$$\Psi\,[m\,.\,.\,.\,.\,.\,.\,.]^4 = 0$$
$$\Psi_1\,[m\,.\,.\,.\,.\,.\,.\,.]^3 = 0$$

This is an extension of a theorem already established with respect to other terms by Poisson and Pontécoulant.

But the same does not hold good with the terms depending on the cube of the disturbing force of the Sun, or involving positive powers of ζ, for the functions

$$q'q''\,[s_0\,s_1]\,[s_0\,s_2]$$

or the function

$$q'\,[s_0\,s_1]''$$

depending on the perturbation of the order of the square of the disturbing force, they do not vanish. Hence the true form of the integrating factors (53) (42) and (45) take the form

$$\begin{aligned}
&\zeta - \{\Psi_2\,[m\,.\,.\,.\,.\,.]^6 + \Psi_3\,[m\,.\,.\,.\,.\,.]^7 + .\,.\,.\,.\,.\}\\
&\zeta - \{\psi_2\,[m^6\,.\,.\,.\,.\,.]^6 + \psi_3\,[m\,.\,.\,.\,.\,.]^7 + .\,.\,.\,.\,.\}\\
&\zeta - \{\psi'_2\,[m\,.\,.\,.\,.\,.]^6 + \psi'_3\,[m\,.\,.\,.\,.\,.]^7 + .\,.\,.\,.\,.\}
\end{aligned} \qquad (54)$$

In the case of the two last of these, this has been verified by actual computation, the term of the orders m^4 and m^5 vanishing, but those of the orders m^6 and m^7 remaining.

The preceding explanation of the methods I have employed in these investigations and the results I have obtained, does not profess to be more than a mere sketch, given to enable the principles of the method to be clearly understood. No attempt has been made to supply the necessary details of the transmission from one step to another, to dwell on any points of interpretation that are involved, or to write out the expressions in sufficient length to enable more to be seen than the general principle. To have done more would have been to extend the space occupied to at least ten times its present amount; and it is unnecessary, as the whole details are embraced in my nearly completed memoir on the theory of these terms of long period. For the present purpose all that is important is the principles on which the results are founded; the details of the transformations and expansions into proper form must be taken as accurate.

It remains, then, to critically examine Delaunay's method of investigating these terms, and to consider certain objections raised to the conclusions submitted in my Paper on "Hansen's Terms of Long Period" (*Monthly Notices*, vol. xxxviii. pp. 268–279, March 1878).

Objection has been raised to my conclusions in that Paper on the ground that they depend on one of the older methods of investigating this subject, whereas Delaunay's results are based

on his own *far more rigorous method.* In the words of a very distinguished astronomer, "You speak of the three parts into which the action of *Venus* on the disturbed motion may be divided. Now this division is a result of the old and imperfect way of viewing the subject; that is, of considering the analytic expressions which give the position of the Moon relative to the Earth as being made up of two parts, certain elliptic terms and certain terms introduced by the action of the Sun. Now the elegance and beauty of Delaunay's method consists in this: that his final equations which express the three co-ordinates of the Moon in terms of these arbitrary constants are not so divided at all, but are *rigorous expressions* for the motion of the Moon around the Earth under the disturbing action of the Sun. Therefore, when by the general equations of dynamics he determines the variations of these constants produced by the action of the planet, the proceeding is rigorous and complete, and that is the end of it." Further, it is claimed that in Delaunay's method of procedure the "differential equations of motion contain all the terms, and any rigorous analytic process of integrating these equations must lead to rigorous results. Now Delaunay *includes all terms of every class in every step.* Hence his results must be correct, unless he has omitted some term through inadvertence."

Now I object to the very basis of these criticisms. I deny absolutely that Delaunay's method of transformed elements is in any manner more rigorous than the methods of perturbed co-ordinates or perturbed elements that have been employed by others. It may be more elegant, it may be more beautiful, it is certainly not more rigorous, whilst it is equally certain it is less simple and less direct than the method of perturbed elements depending on the direct integration of the system of equations (20).

As actually employed in the calculation of the perturbations, or even as capable of so being employed, there is not one of these methods that is strictly rigorous, for all involve numerous approximations, and to the same order of approximations all are equally rigorous and all yield identically the same result.

Though the fundamental equations and transformations involved in Delaunay's method are, I admit, sufficiently rigorous, this is no more than is true to the same degree of the less direct equations and transformations of the older methods; and when Delaunay's method comes to be actually applied, like these others, it sinks into a method of successive approximations where whole series of terms have to be neglected, on the common ground that they appear too small to be of importance. It is true that it is claimed that Delaunay's final equations—that is, the equations after, by successive transformations, all the periodical terms have been removed from the disturbing functions—admit of *rigorous* solution. They admit of *finite* solution, certainly, but scarcely of rigorous solution, as this first stage can only be reached by neglecting whole masses of terms, on

the sole ground that they are beyond a certain arbitrarily fixed limit of supposed smallness. But, exactly the same holds true of the older methods, where, if only you neglect all the terms beyond this same arbitrarily fixed limit, there can be obtained a similarly finite solution.

In truth, the only real difference in principle between Delaunay's method and the method of perturbed elements employed by myself consists in the fact that, whereas I commence by explicitly developing in an algebraical form the entire series of distinct operations, and then replace the algebraical symbols denoting the perturbations as they are successively determined in large masses at a time; on the other hand, Delaunay does not obtain any such algebraical development of his proposed operations, but contents himself with obtaining a new expression for the disturbing function, as he calculates separately the value of the perturbations produced by each distinct term in the expression he successively obtains for this disturbing function. Both, properly conducted, must be equally rigorous. Indeed, if instead of employing the actual values in terms of $(a.e.\eta.n.....)$, Delaunay's method could be employed with algebraical coefficients, there would be derived the same expression for the disturbing function as is obtained as my first step in the method of perturbed elements.

It is scarcely necessary, however, to further discuss this supposed superiority of Delaunay's method, because, whatever preference may be given to it by certain astronomers, it must be admitted that any of the older methods employed by Poisson, Pontécoulant, and Hansen, properly applied, is capable of yielding quite as accurate a solution as Delaunay's, so that if these methods unite in giving a distinct series of terms in addition to those obtained by Delaunay, it is certain that Delaunay has not properly applied his method to this portion of his investigations. Admittedly, the error does not lie in the principle of the method, but in the manner of its application.

It remains to examine the exact manner in which Delaunay has calculated the value of these terms of long period due to the action of the planet *Venus*.

It is generally supposed, as is indicated by the quotations already given, that Delaunay has calculated these terms by a strict application of the method of transformed elements employed by him for determining the ordinary lunar perturbations due to the direct disturbing action of the Sun. But a critical examination of his investigations, published in the *Connaissance des Temps*, Additions 1862 et 1863, will show that this is not the case. For present examination the more important investigation may be selected in the volume for the year 1863.

Delaunay first obtains an expression for the ordinary disturbing function expressing the action of a planet upon the Moon, and corresponding to that designated R, though he retains terms depending on the inclination of the planet to the ecliptic.

These he proceeds to develop in terms of r, r_0 ρ. V_0 V, and the disturbed co-ordinates of the Moon, V and r. He then proposes to replace r^2 and V by their proper values in the actual orbit of the Moon as disturbed by the Sun. This is nominally done by the application of the system of transformation of elements represented by the 492 operations and supplementary operations of his development of the ordinary lunar theory. Suppose this properly done, and the constants replaced by their final values, what would be obtained is purely the second term of the expression (19), or exactly what would have been obtained had he directly replaced r. V..... by their values as the co-ordinates of the Moon as disturbed by the Sun. The expression which forms his final value for R, the disturbing function expressing the action of the planet, should be identically the same expression as I have written in the form

$$\Sigma R_1 A^q \cos(\beta_1 + q\alpha_0). \tag{55}$$

If the same final constants be adopted these two expressions should be identical, term by term, factor by factor.

Delaunay does not retain, however, all the terms of this expression, or, indeed, even attempt to calculate them, but neglects every term except that depending on the particular argument of the term of long period he is calculating. That is, he confines himself to calculating merely the term denoted by me,

$$(R_1 A_0^q)_\Gamma \cos \zeta, \tag{56}$$

or rather the series of allied terms which may be regarded as grouped under the single argument ζ, though differing slightly in the constant portion of their argument.

But really even as much as this is not done. Practically, Delaunay confines himself (*Conn. des Temps*, 1863, App. pp. 7 et 8) to merely writing

$$-a^2 \cdot \tfrac{19}{8} \cdot \frac{n'^2}{\mu^2} \cdot \frac{a'^3}{r'^3} \cdot \cos(2V') \tag{57}$$

for

$$r^2 \cos(2V),$$

which is simply tantamount to neglecting the entire effect of the perturbations of the Moon save those depending on the very first term of the *Variation*.

Delaunay then proceeds to replace

$$\rho r_1 r_0 V_1 V_0$$

by their elliptic values, so as to obtain in detailed form the twelve distinct terms which have been represented, hitherto, by the single term

$$R_1 \cos \zeta,$$

but which really are of the form

$$R_n \cos\{\zeta + (\lambda)_n\}, \tag{58}$$

where $(\lambda)_n$ is a function of the constants denoting the longitude of the perihelia and nodes of the Earth and *Venus*, and differs for each of the twelve terms, although ζ the portion which varies with the time may be regarded as identical in all.

Thus the expression for the values of these terms in the disturbing function which is obtained by Delaunay in this manner is identical with that which can be obtained from (55), the second term of (19), by neglecting all save the first power of the disturbing force of the Sun, and every term in the perturbations of even this order save the factors of the lowest order in the *Variation*. Strictly, it in no sense depends on his method of transposed elements, though made to appear as if it does; nor does it differ in any way from the values hitherto employed by astronomers save in being somewhat less complete.

Delaunay now proceeds to substitute this value of these terms in the disturbing function, in the differential equations adopted by him for determining the value of the resulting perturbations. But he does not employ, as generally supposed, and assumed in the criticisms of my Paper already quoted (page 422), the method of transformed elements which he has used in the other parts of his lunar theory, and founded on the system of equations given on pages 65 and 84, 85 of his 'Théorie de la Lune' (*Mémoires de l'Académie des Sciences*, tom. xxxiii.); but he proceeds to adopt the ordinary differential equations for the variation of elements where the disturbing function R has its ordinary meaning, and does not denote that special value after it has undergone the system of transformation of elements necessary to remove the portion explicitly depending on the ordinary lunar perturbations.

In fact, Delaunay determines the required perturbations from the ordinary form for the differential equation to the variation of the mean longitude l, or from (*Conn. des Temps*, App. 1863, pp. 41 et 42)

$$\frac{dl}{dt} = -\frac{2}{an} \cdot \frac{dR}{da} + \frac{e}{2a^2 n} \cdot \frac{dR}{de}, \tag{59}$$

or practically, as he neglects the second term, from the equation

$$\frac{dl}{dt} = -\frac{2}{an} \cdot \frac{dR}{da}, \tag{60}$$

where he regards a, after differentiating R with respect to a, as being a constant, making the assumption that, as the argument of the term of long period is explicitly independent of l, the mean longitude of the Moon, and as a the mean distance is to be determined from the differential equation

$$\frac{da}{dt} = \frac{2}{an} \cdot \frac{dR}{dl}, \tag{61}$$

there can exist no term with this argument in the value of a, so that this element may be regarded as constant in the preceding equation (60).

Then, writing for convenience the terms in the disturbing function which have this argument in an analogous form to Delaunay, or in the form

$$a^2 \Sigma (B' + B'' m^2) A_n \cos \{\zeta + (\lambda)_n\}, \tag{62}$$

Delaunay, by substitution in the equation (60), obtains expression corresponding to the forms

$$\frac{d l}{d t} = -\frac{1}{n} \Sigma (4 B' + 10 B'' m^2) A_n \cos \{\zeta + (\lambda)_n\} \tag{63}$$

and

$$\delta l = -\frac{1}{\zeta} \Sigma (4 B' + 10 B'' m^2) A_n \sin \{\zeta + (\lambda)_n\} \tag{64}$$

(*Conn. des Temps*, App. 1863, p. 42, formule (*s*)).

This is the value which Delaunay finds for the portion of the coefficient of this term depending on the direct disturbing action of the planet. The portion depending on the more indirect action of the planet as afforded by the perturbations in the mean distance and eccentricity of the Earth's orbit, is then calculated in a similar manner by means of the same differential equations. By uniting these two portions, Delaunay obtains the final value for the term.

The preceding account shows clearly that after calculating the value of R, or rather of these terms in R, in a form corresponding exactly with the value assigned by any of the ordinary methods of developing the disturbing function, Delaunay altogether abandons his special method of transformation of elements, and proceeds to integrate his equations after the ordinary method of variation of elements adopted by Pontécoulant and Hansen.

Out of the numerous assumptions involved in the preceding method by which Delaunay has determined the value of the perturbations with this argument of long period in the expression for the mean longtitude, from the values (58) found by him for the corresponding terms in the disturbing functions, there are two which deserve particular attention. They are:

First, the assumption made in the integration of equation (60), that as the argument ζ is independent of l, the mean longitude of the Moon, it follows that neither

$$\frac{d \mathrm{R}}{d l}$$

nor

$$\frac{2}{a n} \cdot \frac{d \mathrm{R}}{d l}$$

can, either of them, contain a term with the argument ζ; so that the perturbations δa of the mean distance must be free from any such term.

Second, the assumption implicitly involved in his entire treatment of the differential equation to the mean longitude (59), namely that the value of the disturbing function R he has determined in (58) is the complete value of R involved in the differential equation (59), as it is integrated by him so as to obtain the value (64).

The first of these assumptions is certainly unjustifiable, except for terms depending on the first power of the disturbing force. For even if it were admitted that the function

$$\frac{d\,\mathrm{R}}{d\,l}$$

could not contain such terms, it would contain terms of the second order with respect to m and with the argument

$$2\,\theta \pm \zeta,$$

where $2\,\theta$ denotes the argument of the *Variation*. Hence the expression for $\delta\,a$ must also contain terms of the order m^2 with the same argument. Consequently there will arise in the equation

$$\frac{d\,a}{d\,t} = \frac{2}{a\,n} \cdot \frac{d\,\mathrm{R}}{d\,l}$$

terms of the form

$$\frac{d\,a}{d\,t} = \phi(m^4)\,\mathrm{B}\sin\zeta \qquad (65)$$

and the perturbations of the mean distance will contain terms of the form

$$\delta a = -\frac{1}{\zeta} \cdot \phi(m^4)\,\mathrm{B}\cos\zeta. \qquad (66)$$

Now as ζ, the integrating factor of this term of long period, may be regarded as likewise a quantity of the fourth order, it follows that the term in (60) arising from the perturbations in $\delta\,a$ will be of the same importance as those arising directly from the function

$$\frac{d\,\mathrm{R}}{d\,a}.$$

Delaunay has neglected these terms without any attempt to show they are insensible. Hence his result is imperfect.

But the assumption that terms of this form cannot exist in the function denoted by

$$\frac{d\,\mathrm{R}}{d\,l} \qquad (67)$$

is founded on the supposition that

$$\frac{d\,R}{d\,l} + \delta\frac{d\,R}{d\,l} = \frac{d\,R}{d\,l} + \frac{d\,\delta\,R}{d\,l} \qquad (68)$$

which is not true, as the meaning to be assigned to l on the two sides is entirely different, one being the undisturbed or elliptic value and the other the disturbed value. It can easily be shown that terms with the argument ζ will arise in (67) in exactly the same manner as they arose in (65).

It is true that it might be shown that certain of these terms are mutually destructive, but Delaunay has made no attempt to establish this, and it is not true of all these terms, nor completely true of any of them.

It remains to consider the second and more serious assumption made by Delaunay, as it is really the fundamental cause of the difference between the results obtained by him and those obtained by other astronomers using independent methods.

Returning to the expansion of the disturbing function in terms of the elliptic elements and their perturbations, or of the elliptic co-ordinates and their perturbations (19); merely remarking *en passant*, that in these investigations Delaunay uses exactly the same division between the two as employed by myself, though the fact seems to have escaped the attention of the distinguished author of the criticism I have quoted on page 422; I have shown that the complete value of the disturbing function may be conveniently divided into three portions. That is, we may write

$$R = R' + R'' + R''' \tag{69}$$

where these three portions represent the three lines of the expression (19) for R, and

- R′ denotes the portion expressing the sole action of the Sun.
- R″ denotes the portion expressing the action of the planet on the motion of the Moon as disturbed by the Sun.
- R‴ denotes the portions expressing the action of the Sun on the additional perturbations of the Moon due to the action of the planet.

Now it has been shown that both R″ and R‴ contain terms depending on the argument of long period ζ, and so must be both retained in determining the values of the perturbations of this form, though, as R′ does not contain such terms, its consideration may be neglected. Hence the value of the disturbing function which must be employed is

$$R = R'' + R'''$$

Next, the ordinary equations for determining the perturbations by the method of the variation of elliptic elements, by considering only the lowest terms, may be written in the following form:—

$$\begin{aligned} \frac{d\delta a}{dt} &= +\frac{2}{an} \cdot \frac{dR}{dl} \\ \frac{d\delta l}{dt} &= -\frac{2}{an} \cdot \frac{dR}{da} + \frac{e}{2a^2 n} \cdot \frac{dR}{de} \end{aligned} \tag{70}$$

writing down only the first of the three pairs of terms forming the entire set of equations. Hence, on replacing the disturbing function R by its complete value in so far as it involves these terms depending on the perturbing action of the planet, that is by

$$R = R'' + R''' \tag{71}$$

where Delaunay's factor

$$\frac{\mu}{2a}$$

has been regarded as incorporated in R'', so as to bring the expressions into harmony with those of Delaunay, the resulting system of differential equations may be written as

$$\begin{aligned} \frac{d\delta a}{dt} &= \left\{ +\frac{2}{an} \cdot \frac{dR''}{dl} \right\} + \left\{ +\frac{2}{an} \cdot \frac{dR'''}{dl} \right\} \\ \frac{d\delta l}{dt} &= \left\{ -\frac{2}{an} \cdot \frac{dR''}{da} + \frac{e}{2a^2 n} \cdot \frac{dR''}{de} \right\} + \left\{ -\frac{2}{an} \cdot \frac{dR'''}{da} + \frac{e}{2a^2 n} \cdot \frac{dR'''}{de} \right\} \end{aligned} \tag{72}$$

These are the forms which must be used to obtain the complete values of the perturbations of this kind. On integration they lead at once to the values (43) and (46), which have been already given as representing the complete values of these terms as found by Hansen and myself.

Now it has been shown that Delaunay employs these identical equations (70), and obtains his results by integrating them, not according to his own special method, but by integrating them in the ordinary method, such as would have been employed by Poisson or Leverrier. But, when so used and so integrated, it is essential to employ the complete value of the disturbing function given by (71). Delaunay does not do this, for, as it has already been shown, he uses simply the value of the disturbing function which has been denoted by R''. Consequently, the results he obtains are identical with that given by merely the first half of the equations (72), which are exactly the same as the incomplete values (31) and (35).

Hence, Delaunay has neglected the entire series of terms denoted by R''', and the results he has obtained are incomplete. In other words, Delaunay has completely neglected the very class of terms depending on the first power of the disturbing force of the planet, and the square and cube of the disturbing force of the Sun, from which Hansen derives the large values of this class of terms of long period.

This conclusion forms the complete justification of my contention on page 407, and serves to establish the accuracy of the results arrived at in my Paper on "Hansen's Terms of Long Period," in the *Monthly Notices* for March 1878.

Throughout the preceding discussion on pages 425–429 it has been assumed that the equations ultimately employed by Delaunay

in his "Memoir" are meant to be the ordinary differential equations for the variation of elliptic elements, such as are made use of for similar purposes by Poisson (*Mémoires de l'Académie*, tome xiii.), and by Pontécoulant (*Système du Monde*, tome iv.), and by Delaunay himself, for calculating the secular acceleration in the mean motion of the Moon (*Conn. des Temps*, Add. 1861).

Such I believe to have been Delaunay's intention, though it is true that in his investigation he refers solely to his only published Paper on the *Additions de la Connaissance des Temps pour* 1861, pages 7 et 9, a paper on his own special method; a reference the more puzzling as the equations which he uses, and to which he refers, do not appear in this Paper in the form in which he employs them.

To me, Delaunay's idea seems to have been, that having succeeded by his series of transformations in getting rid of all the periodical terms in the portion of the disturbing function depending solely on the Sun, denoted here by R_0, he could regard the differential equations as reduced to expressions depending solely on his final constants (a e γ), and the differentials of the function denoted here by R_1. Hence by neglecting the powers and products of the quantities (e γ n), he was able to regard his equations as reduced to the ordinary differential equations of the method of the variation of elliptic elements, and integrate them accordingly.

But it may be urged that this is not really the case, but that Delaunay intended the ultimate equations (59) and (61) to be regarded as the final equations of his special method of transformed elements, after by successive operations there had been removed all the periodical terms of the portion R_0 of the complete disturbing function which depends solely on the perturbing action of the Sun.

Delaunay has not given these equations in this form as explicit functions of these constants and the differentials of R_1, but they are given by Prof. G. W. Hill on page 245 of his fine memoir on the *Lunar Inequalities due to the Ellipticity of the Earth* (*Astronomical Papers of the American Nautical Almanac*, vol. iii. part ii.). By neglecting terms depending on powers and products of (e γ n), these differential equations may be reduced to the same form as (59) and (61).

Hence it may be urged that the ultimate equations actually used by Delaunay are really the fundamental equations of his special system, so that in varying the method adopted for integrating them from the method of transformation to the method of direct integration, he has only employed a perfectly legitimate variation.

But I do not think that this contention can be regarded as accurate.

The non-periodical portions forming the coefficients of the differentials of R in these final equations of Delaunay's represent merely the non-periodical portion of the functions of the disturbed

elements ($a\ e\ \gamma$) forming the coefficients of the differentials of R in the ordinary equations for determining the variations of the elliptic elements in the disturbed orbit. Hence these final equations of Delaunay's are merely equivalent to the result obtained by completely developing these coefficients in the ordinary differential equations of this form as employed by Poisson or Pontécoulant, by replacing ($a\ e\ \gamma$) by their disturbed values, and then neglecting all the periodical terms. Thus if, in the coefficients of the differentials of R′′ in expression (72), the elements ($a\ e\ \gamma$) be replaced by their complete disturbed values, and the periodical terms be neglected, they will become identical with the corresponding final equations of Delaunay.

Were it permissible, then, to regard the equations (59) and (61) employed by Delaunay in his investigation as merely simplified forms of his final equations, which could be legitimately integrated in the ordinary manner by regarding ($a\ e\ \gamma$) as constants, it would follow that they should lead to results identically equivalent to those given by the first half of the equations (72). In fact, thus integrated, these two expressions do lead to identically the same results, the values actually obtained by Delaunay in his memoir, and corresponding in all respects with the values (31) and (35). But for this to be legitimate, it must follow that the second half of the equations (72) must vanish, and this can only be by the constituent terms mutually destroying each other, and so reducing the whole function to zero.

It is evident, however, that this is impossible.

Moreover, this second part of the equations (72) is the portion which yields the perturbations arising from the disturbing action of the Sun upon the perturbations in the motion of the Moon due to the disturbing action of the planet. Hence, to suppose it to be zero would be equivalent to the theorem that the effect of the disturbing action of the Sun upon the motion of the Moon is independent of any inequalities in this motion due to the action of a planet, or, as these comprise inequalities of every period and all kinds, that it is independent of the existence of any inequalities whatever. This is obviously untrue. Consequently it follows that the second portion of these equations (72) cannot vanish through mutual destruction, and so must not be neglected. Therefore, the quantities ($a\ e\ \gamma$) forming the coefficients of the differentials of R in Delaunay's final equations cannot be regarded as constant, but must be held to be variable, each representing a series of perturbations due to the disturbing action of the planet. But, if variable, the method of integration actually employed by Delaunay is imperfect, and can lead only to imperfect results; he having failed, thus, to take into account the whole class of terms depending on the disturbing action of the Sun and planet, which is represented by the function of R′′′.

It is not difficult to see that the only legitimate ways of integrating the equations (59) and (61), if they be regarded as forms of Delaunay's final equations, are either to employ the

method of transformed elements, and remove by a series of operations all the periodical terms from R_1, the disturbing function depending on the planet, or to replace $(a\,e\,\gamma)$ by their complete values as perturbed elements, and integrate the result in the ordinary manner.

However, it is not necessary to consider the exact nature of the results which would be obtained by either of these methods, for it can be seen that neither of them would lead to the same result as given by the complete value of equations (72), unless an entirely distinct form be given to the expressions for the perturbation of the quantities $(a\,e\,\gamma)$ to that contemplated by Delaunay, and which alone can be derived legitimately from Delaunay's expressions by regarding as complete the value to which ultimately he reduces R_0 by his series of transformations.

Hence there must be some error of principle in the method by which Delaunay thus reduces this portion R_0 of the complete disturbing function to the form

$$\psi(a\,.\,e\,.\,\gamma)$$

where these quantities are variables, supposed capable of being regarded as constants with respect to the periodical perturbations of solar origin, or to be independent of any periodical terms depending on the disturbing action of the Sun.

It remains to point out the origin of this error, and to show clearly the manner in which it has led Delaunay to omit a whole series of terms which ought to have been retained.

This may be best done, perhaps, in the following way:—

Consider, at first, merely the perturbations depending solely on the disturbing action of the Sun. Then the values of the elements of the Moon's orbit may be written in the form

$$\begin{aligned} \mathrm{u} &= u + \Sigma_1^{\infty}\delta_0 u \\ \mathrm{U} &= U + \Sigma_1^{\infty}\,.\delta_0 U \end{aligned} \qquad (73)$$

where

u U denote the non-periodical parts of the variables u U.

$\Sigma_1^{\infty}\delta_0 u$, $\Sigma_1^{\infty}\delta_0 U$ denote the series of periodical terms arising solely from the disturbing action of the Sun.

Employing these variables, the disturbing function must be written in the form

$$\mathrm{R}_0 = \mathrm{M}_0\Sigma_0^{\infty}\psi_0(\mathrm{u}\,.\,\mathrm{U}\,\ldots\ldots)_n \qquad (74)$$

where the mass of the Sun is denoted by M_0.

Delaunay's method consists in replacing the variables u U by the new variables u′ U′, such that

$$\begin{aligned} \mathrm{u}' &= \mathrm{u} - \delta_0 u_1 \\ \mathrm{U}' &= \mathrm{U} - \delta_0 U_1 \end{aligned} \qquad (75)$$

where

$$\delta_0 u_1 \qquad \delta_0 U_1$$

are so determined that when substituted in R_0 they cause the disappearance of the term with the argument$_1$, so that the new value of the disturbing function takes the form

$$R'_0 = M_0\psi'_0(u' \ldots .)_0 + M_0\Sigma_n^{\infty}\psi'_0(u'U' \ldots .)_n \tag{76}$$

from the values of the new variables $u'\,U'$ being such as to cause the disappearance of the periodical term

$$\psi'_0(u'U' \ldots .)_1 \tag{77}$$

by reducing the expression

$$\psi_0(u' \ldots .)_0 + \psi_0(u'U' \ldots .)_1 \tag{78}$$

to the constant term

$$\psi'_0(u' \ldots .)_0 \tag{79}$$

Hence

$$\begin{aligned} u &= \delta_0 u_1 + u' \\ U &= \delta_0 U_1 + U' \end{aligned} \tag{80}$$

and

$$\begin{aligned} u' &= u + \Sigma_n^{\infty}\delta_0 u_n \\ U' &= U + \Sigma_n^{\infty}\delta_0 U_n \end{aligned} \tag{81}$$

By repeated operations of this kind, Delaunay finally reduces his expression to a stage where the variables are

$$\begin{aligned} u^i &= u + \Sigma_{i+1}^{\infty}\delta_0 u_n \\ U^i &= U + \Sigma_{i+1}^{\infty}\delta_0 U_n \end{aligned} \tag{82}$$

and the disturbing function has the form

$$R^i_0 = M_0\psi^i_0(u^i \ldots .)_0 + M_0\Sigma_{i+1}^{\infty}\psi^i_0(u^iU^i \ldots .)_n \tag{83}$$

Delaunay then assumes that all the terms in the perturbations beyond $u_i\ U_i$ are so small that they may be regarded as insensible, so that the terms denoted by

$$\Sigma_{i+1}^{\infty}\psi^i_0(u^iU^i \ldots .)_n \tag{84}$$

may be neglected. Hence his expressions reduce to the form

$$\begin{aligned} u^i &= u \\ U^i &= U \end{aligned} \tag{85}$$

which are constant quantities, and can be determined from the expression for the disturbing function now reduced to the non-periodical term

$$R^i_0 = M_0\psi^i_0(u \ldots .)_0 \tag{86}$$

By these successive operations Delaunay has thus successively determined every term in the complete value of the perturbations

of the elements, whose complete values are now expressed by the known series

$$\begin{aligned} u &= u + \Sigma_1^i \delta_0 u_n \\ U &= U + \Sigma_1^i \delta_0 U_n . \end{aligned} \tag{87}$$

There can be no objection to the principles of this method of determining the perturbations of purely solar origin, or to the admirable manner in which it has been carried out by Delaunay in his "Théorie de la Lune."

Its extension, when it becomes necessary to take into account the perturbation arising from the disturbing action of a planet, is effected by Delaunay in the following manner.

The complete values of the elements of the instantaneous orbit of the Moon become now, for convenience changing the letter used,

$$\begin{aligned} v &= v + \Sigma_1^\infty \delta_0 v_n + \Sigma_0^\infty \delta_1 v_n \\ V &= V + \Sigma_1^\infty \delta_0 V_n + \Sigma_0^\infty \delta_1 V_n \end{aligned} \tag{88}$$

where the additional series of terms are

$\Sigma_0^\infty \delta_1 v_n$ $\Sigma_0^\infty \delta_1 V_n$ denoting the series of terms depending on the disturbing action of the planet.

The complete value of the disturbing function is now

$$R = M_0 \Sigma_0^\infty \psi_0 (v\, V \ldots)_n + M_1 \Sigma_0^\infty \psi_1 (v\, V \ldots)_n \tag{89}$$

where M_1 denotes the mass of the disturbing planet.

As before, Delaunay proceeds to transform the variables v V to the new variables v′ V′, such that

$$\begin{aligned} v' &= v - \delta_0 v_1 \\ V' &= V - \delta_0 V_1 \end{aligned} \tag{90}$$

where, as before,

$$\delta v_1 \, \delta V_1$$

are so determined that when the new variables are substituted in R they cause the disappearance of the periodical term with the argument 1, so that the new value of the disturbing function has the form

$$R' = M_0 \psi_0 (v' \ldots)_0 + M_0 \Sigma_2^\infty \psi_0 (v'\, V' \ldots .)_n + M_1 \Sigma_0^\infty \psi_1 (v'\, V' \ldots)_n \tag{91}$$

Hence, as before,

$$\begin{aligned} v &= \delta_0 v_1 + v' \\ V &= \delta_0 V_1 + V' \end{aligned} \tag{92}$$

and

$$\begin{aligned} v' &= v + \Sigma_2 \delta_0 v_n + \Sigma_0^\infty \delta_1 v_n \\ V' &= V + \Sigma_2^\infty \delta_0 V_n + \Sigma_0^\infty \delta_1 V_n \end{aligned} \tag{93}$$

By repeating the same series of operations as before, Delaunay reaches, at last, the same stage where he ended the transformations in the case of the perturbations due solely to the action of the Sun, the stage where the variables have been reduced to

$$\begin{aligned} v^i &= v + \Sigma_{i+1}^{\infty} \delta_0 v_n + \Sigma_0 \delta_1 v_n \\ V^i &= V + \Sigma_{i+1}^{\infty} \delta_0 V_n + \Sigma_0^{\infty} \delta_1 V_n \end{aligned} \tag{94}$$

and the disturbing function has the form

$$R^i = M_0 \psi_0^i (v^i \dots)_0 + M_0 \Sigma_{i+1}^{\infty} \psi_0^i (v\ V \dots)_n + M_1 \Sigma_0^{\infty} \psi_1^i (v^i V^i \dots) \tag{95}$$

Then, by neglecting as insensible the same quantities as before, Delaunay reduces these expressions (94) and (95) to

$$\begin{aligned} v^i &= v + \Sigma_0 \delta_1 v^n \\ V^i &= V + \Sigma_0^{\infty} \delta_1 V_n \end{aligned} \tag{96}$$

and

$$R_i = M_0 \psi_0^i (v \dots)_0 + M_1 \Sigma_0 \psi_1^i (v\ V \dots)_n \tag{97}$$

whilst the original variables take the form

$$\begin{aligned} v &= v + \Sigma_1^i \delta_0 v_n + \Sigma_0^{\infty} \delta_1 v_n \\ V &= V + \Sigma_1^i \delta_0 V_n + \Sigma_0^{\infty} \delta_1 V_n \end{aligned} \tag{98}$$

the last terms of these expressions (98) being still so far arbitrary, inasmuch as they have not yet received determinative values.

The preceding shows clearly the manner in which Delaunay reduces the value of the first term of the complete disturbing function (89) from

$$R_0 = M_0 \Sigma_0^{\infty} \psi_0 (v\ V \dots)_n \tag{99}$$

to the value

$$R_0' = M_0 \psi_0^i (v \dots)_0 \tag{100}$$

which he employs as the value of this portion of R to be used in the differential equations (59) and (61), so as to determine the complete value of the perturbation arising from the disturbing action of the planet, denoted here by

$$\Sigma^{\infty} \delta_1 v_n \qquad \Sigma_0^{\infty} \delta_1 V_n$$

The question is now, has this reduction from (99) to (100) been legitimately effected, without omitting terms which ought to have been retained?

To this I reply, 'No!'

Compare the two series of transformations (75) and (90). In the first we have the value

$$v' = v - \delta_0 v_1$$

in the second the value

$$v' = v - \delta_0 v_1$$

Now, throughout his investigation Delaunay assumes the complete identity of the two series

$$\Sigma_1^{\infty} \delta_0 u_n = \Sigma_1^{\infty} \delta_0 v_n$$

so that we have

$$v' = v - \delta_0 u_1 \tag{101}$$

and so by (73) and (88)

$$v = u + \Sigma_0^{\infty} \delta_1 u \tag{102}$$

the preceding expression (101) becomes

$$v' = u - \delta_0 u_1 + \Sigma_0^{\infty} \delta_1 v_n \tag{103}$$

Hence

$$v' = u' \left\{ 1 + \frac{\Sigma_0^{\infty} \delta_1 v_n}{u'} \right\} \tag{104}$$

Now the entire validity of Delaunay's method of calculating the perturbations of this planetary origin rests on the assumption made in passing from (89) to (91), that as the operation of transforming the variables from u U to u′ U′ reduces the periodical expression

$$\psi_0(u' \ldots\ldots)_0 + \psi_0(u'U' \ldots\ldots)_1$$

to the non-periodical expression

$$\psi_0'(u' \ldots\ldots)_0$$

(77) to (79), so will *identically* the same operation with the variables v V and v′ V′ reduce the periodical expression

$$\psi_0(v' \ldots\ldots)_0 + \psi_0(v'V' \ldots\ldots)_1$$

to the non-periodical term

$$\psi_0'(v' \ldots\ldots)_0$$

Hence, Delaunay's entire method rests on the assumption that because

$$\psi_0(u' \ldots\ldots)_0 + \psi_0(u' . U' \ldots\ldots)_1 - \psi_0'(u' \ldots\ldots)_0 = 0 \tag{105}$$

so must

$$\psi_0(v' \ldots\ldots)_0 + \psi_0(v'V' \ldots\ldots)_1 - \psi_0'(v' \ldots\ldots)_0 = 0 \tag{106}$$

For simplicity, put

$$\begin{aligned} j &= \Sigma_0^{\infty} \delta_1 v_n & J &= \Sigma_0^{\infty} \delta_1 V_n \\ D_j &= \frac{d}{u' du'} & D_J &= \frac{d}{U' dU'} \end{aligned} \tag{107}$$

then by (104), expanding by a symbolical form of Taylor's Theorem

$$\psi_0'(v' \ldots\ldots)_0 = \left\{ e^{jD_j} \right\} \psi_0'(u' \ldots\ldots)_0$$

$$\psi_0(V' \ldots\ldots)_0 = \left\{ e^{jD_j} \right\} \psi_0(u \quad \ldots\ldots)_0 \qquad (108)$$

$$\psi_0(v'\, V' \ldots\ldots)_1 = \left\{ e^{jD_j + JD_J} \right\} \psi_0(u'U' \ldots\ldots)_1$$

Hence (106) may be written in the form

$$\left[e^{jD_j} \right] \left\{ \psi_0(u' \ldots\ldots)_0 + \psi_0(u'U' \ldots\ldots)_1 - \psi_0'(u' \ldots\ldots)_0 \right\}$$
$$+ \left[e^{jD_j} \right] \left[e^{JD_J} - 1 \right] \left\{ \psi_0(u'U' \ldots\ldots)_1 \right\} = 0 \qquad (109)$$

By (105) the first term of this is equal to zero, hence Delaunay's assumption reduces to the condition that

$$\left[e^{jD_j} \right] \left[e^{JD_J} - 1 \right] \left\{ \psi_0(u'U' \ldots\ldots)_1 \right\} = 0 \qquad (110)$$

and unless this condition hold generally true, Delaunay's method fails, for he has omitted the entire series of terms represented by the function on the left-hand side of (110).

By replacing by their known equivalents the function

$$e^{jD} \qquad e^{JD_J}$$

the value of the left-hand side of (110) may be written in the form

$$\left\{ \left[1 + \Sigma_0^\infty \delta_1 v_n \cdot \frac{d}{u'du'} \cdot + \ldots\ldots \right] \left[\Sigma^\infty \delta_1 V_n \cdot \frac{d}{U'dU'} \quad + \ldots\ldots \right] \right\}$$
$$\psi_0 (u'\, U' \ldots\ldots)_1 \qquad (111)$$

It is evident that this expression will represent a series of periodical terms which cannot vanish, either invariably or even generally; and they will thus form an important portion of the transformed value of R, which has been uniformly neglected by Delaunay. Thus the reduction from (99) to (100) has only been effected by neglecting an important portion of the complete value of the disturbing function.

It would not be difficult to show, were it necessary, that the terms represented by (111), which have been omitted by Delaunay, correspond exactly with those represented by the third portion of the disturbing function denoted by R''' in my developments (19) and (69), which yield the second portion of the equation (72). And their omission by Delaunay explains the discordance between the results obtained by the two methods.

It follows, therefore, that the method employed by Delaunay does not yield the complete value of the coefficients of equation of long period due to the disturbing action of the planet.

The importance of this result is evident.

First, there is thus explained the discordance between the

results obtained by myself by the methods which I have explained above, and the results obtained by other astronomers for the same terms of long period by means of Delaunay's method.

Second, what is far more important is its results with regard to the comparison between theory and observation. My own researches have shown clearly that if Delaunay's values for these terms be accepted as accurate, it is impossible to reconcile the theory of the Moon with the results of actual observation without assuming the existence of a large inequality of long period, which can only be due to the disturbing action of a planet. Now, unless Delaunay's method of determining the value of these terms be incorrect, there cannot exist such an inequality. Every one which could possibly yield a sensible coefficient by Delaunay's method has been carefully examined by me. They number over one hundred, but not a single one can have a maximum value of nearly one second, whereas to reconcile theory and observation there is required a term with a coefficient of twelve seconds (*On the Corrections to Hansen's Tables de la Lune. Memoirs R. A. S.*, vol. xlviii. p. 372). Hence an apparently unsurmountable discordance between theeory and observation.

But Delaunay's method now having been shown to be imperfect, there are two methods at once available for meeting this difficulty. First, as I have shown already (*ibid.*, page 371), by assuming smaller and more probable values for the coefficients of Hansen's two Venus terms to those employed by him in his tables. This suffices to remove by far the greater part of the existing discordance, and the coefficients of these terms thus indicated by observation agree fairly well with the results of my approximate theoretical computations. Second, by rendering it possible that the whole remaining discordance between the results of theory and observation may be removed ultimately by the calculation of the values of the terms of long period which are known to exist; for though it is evident that the coefficients of these terms will be too small to be of any importance when they are calculated by Delaunay's method, it may be anticipated that many of these coefficients will be found to be much larger when calculated by one of the complete methods that have been described in the first portion of this Paper, so that some may be found large enough to remove the outstanding discordances.

In conclusion, perhaps it will be as well to add a few words on the exact condition of my own investigation of these terms. They have been carried out quite independently by both of the two methods already described, namely, the method of disturbed co-ordinates, and the method of perturbed elements. They are already so far advanced as to only require the calculation of some supplementary terms to be prepared by final revision for reduction to numbers, so as to enable me to use them to obtain complete results. A considerable amount of additional work, however, must necessarily be involved in preparing such a memoir for

publication. Ill-health, unfortunately, has completely prevented my touching them for nearly a year, but I hope that before the end of this year I shall be able again to resume my labours, and bring them to an early close. The work is one of very great length, as many of the coefficients have had to be carried to the tenth order of small quantities. I do not hesitate to say that it involves as much work as is necessary to carry to the seventh order the calculation of the ordinary lunar perturbation of purely solar origin, such as form the contents of the two great volumes constituting Delaunay's "Théorie de la Lune." For it is to be remembered that by far the greatest portion of the labour has been neglected by those astronomers who have employed Delaunay's method, and who have in consequence had to face scarcely one-tenth of the work necessary to calculate the complete value of the coefficients of these terms of long period due to the disturbing action of the planets.

Moreover, the work which is being carried out by myself embraces in one plan the computation of the entire series of nearly fifty terms of long period due to the disturbing action of the different planets, which I have reason to believe have coefficients of sufficient magnitude to render it advisable that they should be retained in any future lunar tables. It would be most inconvenient, therefore, and would involve much additional labour, for me to have to select from the whole mass of computations, and to piece together in a fit state for publication, the numerous detached portions of the whole which relate to those particular terms of long period. And if the accuracy of my values for their coefficients has been questioned by other astronomers, it has been on the basis of investigations which I have shown, in the present Paper, to rest on an imperfect method.

I think, therefore, it is the more preferable course to wait until I have completed the whole investigation, and am in a position to publish entire, my memoir on these important perturbations in the motions of the Moon.

The Natal Observatory,
May 1, 1886.

Supplementary Measures of the Magnitudes of a Zone of Stars near the Equator for reference as Standards of Magnitude in lieu of Polaris. By Prof. C. Pritchard, D.D., F.R.S.

In the course of the last twelve months I have had the photometric remeasurement of about fifty stars near the equator effected. These stars are of approximately the magnitudes four and six, and may well serve as stars of comparison for other stars, whether north or south of the equator, and may be used for such comparison within any magnitudes from the first to the ninth without reference to *Polaris* when such reference is incon-

venient. Moreover, in comparing the magnitude of southern stars, the uncertain correction for atmospheric absorption may be avoided, and the relative brightness of stars in the southern hemisphere can be connected with those already determined in the north, systematically, and on the same scale.

In the text of the "Uranometria Nova Oxoniensis" the magnitudes of the stars in this zone have been determined for the most part from twenty extinctions on one night. In the present supplement, the results have been obtained from measures made on at least five nights, so that the concluded magnitudes now depend on, in general, seventy extinctions. I think, therefore, that these magnitudes are worthy of very considerable confidence. In the supplementary table here presented, the fourth column contains the magnitude already given in the "Uranometria Nova Oxoniensis," the second is the concluded magnitude derived from all the extinctions of the several nights of observation. It is, I think, highly satisfactory to find that no important corrections are to be made to the original determinations.

Star's Name.	R.A. 1890.	N.P.D. 1890.	Old determination of Magnitude in "Uran. Nov. Ox."	New determination of Magnitude 1885–86.
	h m	° ′		
P. 0.146	0 35·1	94 57	6·25	6·19
δ Piscium	0 43·0	83 1	4·32	4·43
88 Piscium	1 9·0	83 35	6·01	6·03
ν Piscium	1 35·7	85 4	4·68	4·65
P. ii. 52	2 12·3	88 46	6·02	5·97
ξ^2 Ceti	2 22·3	82 2	4·66	4·56
95 Ceti	3 12·7	91 20	5·77	5·72
κ Ceti	3 13·6	87 2	5·15	5·04
40 Tauri	3 58·0	84 52	5·56	5·51
P. iv. 49	4 14·9	84 8	6 02	6·02
Lal. 9579	4 59·4	93 12	6·00	6·05
π^6 Orionis	4 52·9	88 27	4·74	4·70
ψ^1 Orionis	5 19·0	88 15	4·61	4·57
P. v. 206	5 39·2	86 2	6·09	6·10
D.M. +2° No. 1237	6 21·6	87 1	6·00	6·00
10 Monocerotis	6 22·5	94 42	4·82	4·82
13 Monocerotis	6 27·0	82 35	4·78	4·59
Lal. 13799	7 1·9	82 21	6·06	6·05
β Can. Min.	7 21·2	81 29	3·11	3·10
Lal. 15136	7 40·7	96 30	5·98	5·96

Star's Name.	R.A. 1890.	N.P.D. 1890.	Old determination of Magnitude in "Uran. Nov. Ox."	New determination of Magnitude 1885–86.
	h m	° ′		
30 Monocerotis	8 20·2	93·33	3·63	3·64
D.M. – 1° No. 2125	8 40·4	91 39	...	6·06
21 Hydræ	9 7·0	96 40	6·20	5·99
ι Hydræ	9 34·2	90 39	4·36	4·37
12 Sextantis	9 54·0	86 5	6·73	6·67
23 Sextantis	10 15·4	87 9	6·79	6·74
30 Sextantis	10 24·7	90 4	5·02	5·07
55 Leonis	10 50·1	88 41	6·20	6·10
σ Leonis	11 15·5	83 22	4·15	4·13
h Virginis	11 54·3	85 44	5·36	5·32
χ Virginis	12 33·6	97 23	4·67	4·67
δ Virginis	12 50·1	86 0	3·47	3·49
46 Virginis	12 54·9	92 47	5·97	5·94
ζ Virginis	13 29·2	90 2	3·36	3·33
80 Virginis	13 29·8	94 50	5·91	5·89
W.B. xiv. 143	14 10·8	92 41	6·02	6·03
μ Virginis	14 37·3	95 11	3·86	3·85
Lal. 27297	14 53·9	84 59	6·31	6·30
ψ Serpentis	15 38·5	87 8	5·83	5·84
μ Serpentis	15 43·9	93 6	3·30	3·33
21 Herculis	16 18·7	82 48	5·94	5·95
κ Ophiuchi	16 52·3	80 28	3·17	3·22
P. xvi. 289	16 59·9	90 45	5·68	5·62
γ Ophiuchi	17 42·4	87 15	3·83	3·78
W.B. xviii. 28	18 4 4	86 53	5·86	5·78
Lal. 35281	18 50·7	91 56	6·05	6·08
δ Aquilæ	19 19·9	87 6	3·36	3·33
σ Aquilæ	19 33·8	84 51	4·88	4·77
71 Aquilæ	20 32·7	91 29	4·63	4·57
7 Pegasi	21 36·8	84 49	5·41	5·41
28 Aquarii	21 55·4	89 56	5·85	5·75
η Aquarii	22 29·7	90 41	4·12	4·14
3 Piscium	22 55·0	90 24	6·48	6·38
ι Piscium	23 34·3	84 58	4·25	4·27
21 Piscium	23 43·8	89 32	6·11	6·09

Since the completion of the "Uranometria Nova Oxoniensis" the method of stellar photography has been notably improved, mainly by the methods adopted and set forth by Mr. Common in England and by the Messrs. Henry at Paris.

For my own part, I have, at the Oxford University Observatory, studied this method with, I trust, considerable success, and the several results of this research have been communicated to the Royal Society. I mention this fact here, because I believe it will be found that the photographic method, properly applied, is pre-eminently adapted to the photometry of the fainter stars, including all fainter than the seventh magnitude.

The relation which in these researches is established between the photographic diameters of the discs of stars impressed on the *same plate* during one exposure of the film is

$$D - D' = \delta\{\log M' - \log M\}$$

where D and D′ are the measured diameters of the discs of any two stars and M, M′ their corresponding magnitude, δ being a constant determined from that plate. The preceding formula when translated into words indicates that, while the numerical magnitude increases in geometrical progression, the diameter diminishes in arithmetic. The magnitudes thus obtained are, strictly speaking, photographic; but for the great majority of stars possessing no peculiarity in their actinism or spectra, these photographic magnitudes correspond with the photometric.

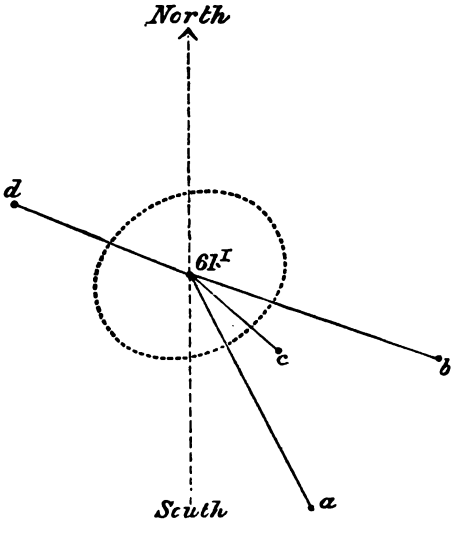
In practice it is necessary to measure photometrically the magnitudes of three or four out of the stars impressed on the plate, when the formula above will give the magnitudes of the remaining stars, after measuring the diameters of their discs, either with a double-image micrometer or by any other suitable means. (See "Proceedings of the Royal Society" for May 1886.)

On a Remarkable Instance of the Detection of Distortion in a Photographic Film, measured for the purpose of Stellar Parallax. By Prof. C. Pritchard, D.D., F.R.S.

In the new and important relations recently established between photography and observational astronomy, any communication, however trifling, relating thereto, so long as it is accurate and sincere, may be acceptable to the Society. In this view I enclose an account of a somewhat remarkable condition, in which I have twice found a photographic film, which at once conveys a warning and encouragement in the use of stellar photography when applied to precise instrumental measurement.

The case here in question refers to photographs of the two stars, 61^1 and 62^2 *Cygni*, and neighbouring stars. The object is

the somewhat ambitious, and maybe hazardous, attempt to extract (as a first trial of a new method) the parallax of this well-known star from the careful measures of the distances of four stars of comparison from the two components of 61 *Cygni*. The following is a diagram, drawn to scale, of the stars in question. The dotted ellipse indicates the approximate form and position of the parallactic ellipse, of course enormously enlarged. The plates are usually exposed for not more than five



minutes, the object being to limit the diameter of the stellar discs to the smallest dimensions compatible with distinct impressions of the fainter comparison stars on the film. With much longer exposures the stellar discs would be more difficult in their instrumental bisection. Moreover, the two discs of 61 *Cygni* might probably coalesce. The circumstances to which I desire to call attention are these:

On each of eight plates, taken on four contiguous nights, the distances of the stars *a* and *b*, from 61^1 and 61^2 *Cygni* have been measured, as also the distances of the stars *c* and *d* from the two components. These measures, as regards seven of the plates, exhibit very satisfactory agreement *inter se* when fully reduced for refraction and aberration, presenting a probable error not exceeding the tenth of a second of arc, promising so far, but so far only, the ultimate success of the research. But on one of these plates there is this remarkable fact, viz. the distances of the stars *a*, *b* and *c* from 61^1 and 61^2 are each definitely less (by about $1''{\cdot}2$) than the corresponding measures on all the other seven plates. This would of itself indicate a disturbance of the film in the neighbourhood of either 61 or of

a, *b*, *c*. The fact of this disturbance on the eighth plate is not only confirmed, but is actually localised by the measures of the star *d*, from 61^1 and 61^2, for this measure is in good accordance with the similar measures on all the other seven plates.

The film has therefore been disturbed in the neighbourhood of *a*, *b*, *c*, and remained unimpaired in other parts. From these results I think we may fairly deduce the reliability of the whole process, both in regard to the ultimate precision, and the power of detecting flaws in the photographic film. It may be well to state that the delicacy of the measures does not extend beyond the hundred-thousandth of an inch on the film, amounting to about 0″·07. The plates are purposely confined to two inches square, embracing the limit of accuracy of the telescopic field, whilst beyond these dimensions the photographs might resemble pictures rather than accurate charts, capable of exact measurement.

Oxford University Observatory,
1886, *June* 10.

On the Orbit of ζ Sagittarii. By J. E. Gore.

This bright southern star was discovered to be double many years ago by Winlock with the 15-inch Refractor of the Harvard Observatory. Very few measures of it have been made, but those by Burnham in 1878–1881 show that it is undoubtedly a binary in very rapid motion.

I have computed the orbit by the graphical method described in the "Handbook of Double Stars" by Messrs. Crossley, Gledhill, and Wilson.

The observations used are as follows:—

Epoch.	Position Angle.	Distance.	Observer.
1867·8	260°·8	0″·48	Newcomb
1878·70	84·2	0·42	Burnham
1880·62	62·1	0·55	„
1881·61	36·1	0·31	„

From these I have computed the following provisional elements:

Elements of ζ Sagittarii.

P = 18·69 years	$\Omega = 83° 22'$
T = 1882·86	$\lambda = 263° 21'$
$e = 0·1698$	$a = 0''·53$
$\gamma = 58° 48'$	$\mu = -19°·26$

The observations are, of course, much too few to enable a satisfactory orbit being computed, but I think the observed measures

show that the period found above cannot be very far from the truth. With the exception of ξ *Equulei*, it seems to be the shortest period yet computed for a binary star.

The following is a comparison between the recorded observations and the positions computed from the above elements :—

Epoch.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1867·8	260°·8	260°·2	+0°·6	0″·48	0″·51	−0″·03
1878·70	84·2	85·0	−0·8	0·42	0·53	−0·11
1880·62	62·1	61·4	+0·7	0·55	0·40	+0·15
1881·61	36·1	38·2	−2·1	0·31	0·29	+0·02

Owing to the closeness of the components, and the great southern declination of the star, it cannot be well measured in this country. It is therefore to be hoped that observers in the Southern Hemisphere will pay some attention to this interesting binary during the autumn of 1886 and 1887. If the above elements are correct, the position-angle and distance must at present be nearly the same as when the star was measured in 1867, a complete revolution having been performed in the interval, and no more favourable opportunity of measuring it will occur till the year 1896.

The position of the star is for 1886·0

R.A. $18^h\ 55^m\ 21^s$

S. 30° 3′ 20″

The formulæ for calculating an ephemeris are

$$u-9\cdot728 \sin u = -19°\cdot26\ (t-1882\cdot86)$$

$$\tan \tfrac{1}{2}V = 1\cdot19 \tan \tfrac{1}{2}u$$

$$\tan\ (\theta_c-83°\ 22') = 0\cdot5180 \tan\ (V+263°\ 21')$$

$$\rho = 0''\cdot53\ (1-0\cdot1698 \cos u).\frac{\cos\ (V+263°\ 21')}{\cos\ (\theta_c-83°\ 22')}$$

where u is the eccentric anomaly, and V the true anomaly for the time t, θ_c the required position-angle, and ρ the distance.

The magnitudes of the components are about 3·5 and 4·0.

1886, *May* 25.

The Northern Hemisphere of Mars. By N. E. Green.

It has been considered advisable to re-examine the details of the northern hemisphere, in order to correct or improve the map of *Mars* published in connection with the Madeira Series in 1877, that portion of the map being formed from drawings made in 1873, and considered provisional.

A careful study of the northern markings was made by Mr. Knobel in 1884, and during the recent opposition the writer has

followed the planet with renewed attention. The result of these observations has been the confirmation of many of the old forms and the filling in of details over an extensive portion of the surface lying between longitude 90° × 180°, which part was nearly a blank in the map of 1877.

Some differences exist between that map and the one produced by Mr. Knobel from his observations in 1873 and 1884, to which special reference is made in this paper.

The instrument employed in the recent observations is an 18-inch Reflector; the speculum was figured by Mr. G. With of Hereford, and is of the highest quality. The powers employed varied between 280 and 560, the latter being used most frequently. The details of the northern hemisphere of *Mars* require steady air and great amplification in order to form a true estimate of their shapes, and it was found that the more delicate markings could not be drawn without the assistance of a power of 400. Many forms of eyepiece were tried, but that which gave the best results was a binocular of the usual microscopic shape, screwed to a tube connected with the adjusting rack. As this binocular eyepiece gives an erect view, it was considered better to complete a series of drawings in this new position, without comparing them with previous views till they were finished; and it was very interesting to observe afterwards how the forms which at the telescope appeared new and strange fell into their places, and in many instances agreed closely with the map of 1877. A copy of this map, together with a new one of the northern portion, produced from the drawings made this year, accompanies the paper.

On comparing these maps, it will be seen that from longitude 0 to 60° there is but little change, though Airy Sea is now a less definite form. From 90° to 180° an entirely new set of markings appear, some of them strongly resembling the light mark called Fontana Land at longitude 210°. These shapes were singularly definite, and of the truth of their forms and colour the observer has no doubt.

Huggins Inlet, passing from Maraldi Sea across the equator towards Fontana Land, has been observed on several occasions, but appeared as a broader and fuller mark than in the views by Mr. Knobel and others.

From longitude 210° to 300° there is no definite change. The termination of Nasmyth Inlet, called Lassell Sea, has been a most prominent mark during the opposition just past, but less extended towards the equator than as drawn in the older map. The light space called Leverrier Land has been seen as a clear separation between Lassell and Knobel Seas. It is at this portion of the map Mr. Knobel thinks that corrections should be made, but the most close and continued observation has failed to discover any decisive difference of shape between the forms observed in 1873 and during the past opposition.

It is but just to remark that in 1884 a drawing was made of

the termination of Nasmyth Inlet which agrees exactly with the description of its shape at page 280 of Mr. Knobel's Memoir; and certainly during that opposition there was no approach to the definite rounded form seen this year.

I am indebted to Mr. Denning of Bristol and Mr. Smart of London for several views of *Mars*; and the drawings of both these observers confirm the existence of Lassell Sea as a roundish spot.

One of the most marked features of the opposition now past has been the frequent appearance of masses of light on the limb which never arrive at the meridian, and that the orange portions of the surface so frequently seen on the meridian do not retain this colour as they pass towards the limb, but become whitish. May not this suggest that cloud condensation prevails on the right side of the planet, and that these masses of cloud are dispersed as they pass the meridian towards the Sun?

The character of the markings on *Mars*, the difficulty of observing, and still more the difficulty of drawing them, will continue to make this planet, if not a satisfactory, at least a most interesting, object of study.

On the asserted Foreshortening of the Inner Side of the Penumbra of Spots when near the Sun's Limb. By Rev. F. Howlett.

I am desirous of placing on record some definite statements and measurements in connection with the appearance of certain symmetrically shaped solar spots, both when near the centre and also when close to the limb of the Sun.

It will be found that these measurements entirely militate against the commonly received opinion that the spots are to any such extent sunk in the solar surface as to produce always those effects of perspective foreshortening of the inner side of the penumbra (when near the limb) which have been described in various works on Astronomy, and founded chiefly, I believe, on statements made as long ago as the year 1769 by Dr. Wilson of the University of Glasgow.

These statements and observations on the part of Dr. Wilson are so extremely circumstantial that I am far from desiring to call them in question, though I beg to be allowed to affirm that they at any rate do not always hold good.

Dr. Wilson's statements are thus alluded to in Mr. Proctor's very full and interesting popular work *The Sun*, ed. 1871, p. 169. "In November 1769 Dr. Wilson began the careful study of a large spot (visible to the naked eye). . . . When he first examined the spot (Nov. 22) it was situated not very far from the western or 'preceding' edge of the Sun's disk.

"On the next day he found that the spot had changed its appearance. The penumbra, which on the previous day was

equally broad on all sides of the nucleus [or as we should now say, more precisely, the umbra], was now very much contracted on the side which lay towards the centre of the disk, while the other parts retained nearly their former dimensions. On the 24th he again observed the spot. The distance from the limb was now only twenty-four seconds, and the contracted side of the penumbra had entirely vanished. . . . The breadth of the nucleus [umbra] on the same side also appeared to be more suddenly impaired than it ought to have been by the motion of the Sun (*sic*) across the disk.

"Dr. Wilson showed that these results correspond with those which would follow if the spot was a vast cavernous opening, having the nucleus at the bottom, and the penumbra forming its sloping sides.

"It only remained to be seen whether a corresponding succession of changes occurred when the spot reappeared on the eastern edge, and thence passed across the solar disk. This actually happened. On December 11 the spot appeared on the opposite side of the disk. The side of the penumbra next the edge, which formerly vanished, was now wholly visible, while that turned towards the centre of the disk appeared to be wanting. On December 12 it [that is, this part of the penumbra] came into view, and he saw it distinctly, though narrower than the other side. He did not see the spot again till December 17, when it had passed the centre of the disk, and the penumbra appeared to surround the nucleus [umbra] equally on all sides."

Not, however, that such statements, however well attested on the above occasion, have always remained unchallenged. For instance, on the occasion of the eleventh General Assembly of the Astronomical Society, convened at Geneva in the month of August 1885, Professor Spörer of Munich, in a copious *résumé* of his labours in connection with the solar spots, denies that the spots possess the character of funnels (*tonnoirs*), which is attributed to them in the greater number of works on elementary astronomy. The appearances which attend the disappearance of spots on the Sun's western limb cannot, he affirms, be explained by such a theory. "When a spot," he says, "is very shortly about to disappear, by virtue of the Sun's rotation on his axis, the two *lateral* borders of the penumbra vanish from sight, whilst the nucleus [umbra] remains visible, together with the fragments of the surroundings (*pourtour*) to the north and south; the whole phenomena," he says, "presenting the appearance of a veiled brightness (*éclat voilé*) to such a degree that one might easily confound the nucleus [umbra] itself with its surroundings," and of which typical and striking instances may be seen in vol. ii. sheet 99, and still more sheet 108, of my drawings.

Spörer then seeks to explain this appearance by a heated facular border surrounding the spot, and causing an ascending current of extremely heated gas, through which it is with the

greater difficulty that the spot is discerned the nearer it is to the limb.

He then remarks, very justly, that it is "by no means the case that all spots are suitable for the estimation of the pretended parallax of the depth of a spot; and in making use of documents on this subject one is far from arriving at results similar to some of those which have been published; and that in all attempts to make drawings of the spots there is a danger of falling into grave illusions."

In my contention, again, that by no means the majority of spots present that funnel-like appearance attributed to them by the Wilson hypothesis, I am sufficiently borne out both by Father Perry and Mr. Ranyard. The former, after paying especial attention, at my request, to this point in connection with a large and unusually symmetrical spot which was close to the western limb on the afternoon of April 12 of this present year, wrote me thus:—"The question of the foreshortening was specially attended to, and the observation showed a very slight excess of foreshortening on the side of the penumbra nearest the Sun's centre, but certainly not enough to give any support to Wilson's theory." Mr. Ranyard, again, in a letter of the 7th inst., reports:—"I had a good look at your spot on the morning of Wednesday, June 2, and I again had a search for it on the morning of June 4" (when, I may observe, it had quite passed off the limb). "I quite agree with you," he says, "that there was no appreciable difference in the breadth of the penumbra on the preceding and following sides of the nucleus" (umbra, again, is here meant) "when I observed it on the morning of Wednesday, June 2. I was observing it between 9^h 20^m and 10^h A.M., and I thought that the penumbra was a little *darker* on the preceding than on the following side, but not very noticeably so. There was no band of increased darkness such as would have been produced by a column of absorbing matter rising vertically above the nucleus. I quite agree with you that the phenomena observed did not tend to support Wilson's hypothesis."

With respect to this last spot, Father Perry's observations do not confirm my own to the same extent, apparently, as was the case in connection with the spot γ of April last, though it is on that of June 2 that I would rely, if possible, more firmly than on the rest. Together with some small but beautifully executed copies of the sketches of spots made recently at Stonyhurst, Father Perry wrote as follows:—"You will notice that near the edge there appears to be a slight confirmation of Wilson's theory at both limbs of the Sun." And he adds, "In some of our drawings of solar spots this is much more marked; but these probably are different classes of spots, and all certainly do not behave alike."

But now as to actual *measurements* of what I would term the crucial spots γ of April 12, and λ of June 2.

I first noticed γ on April 2, at 7^h 30^m A.M., when it was about

2′ 48″ from the eastern limb, and perceiving that the umbra was nicely central, and the whole spot neatly oval, I resolved to keep the spot under observation, with the view of testing the hypothesis in question. It was then about 50″ in length from north to south, and, as then, foreshortened on the sphere, about 40″ in breadth from east to west. On April 6 the size of the spot was somewhat diminished, but its neatness and suitability for testing the hypothesis was still more apparent, for a more perfectly central umbra or symmetrical penumbra could not be wished for. The spot at $10^h\ 20^m$ A.M. that day was not far from the centre of the disk, and subtended about 45″ in length and the same in breadth. When at length, on April 12, the spot had arrived very near to the western limb, I made the following notes: At $4^h\ 20^m$ γ was only about 10″ from the western edge of the Sun, and subtended not more than 10″ in breadth. The umbra still appeared quite central, with a width of not more than 2″. Each side of the penumbra measured also about 2″ in breadth, or possibly the "preceding," or outer, side, 2″, and the following 1″·8, but of this I could not be quite certain.

I may observe also, in passing, that on May 9 a spot lettered ι, when about 18″ only from the western limb, and measuring 40″ in length and 8″ in breadth, presented a perfectly central umbra 3″ in width; here again militating against Dr. Wilson's hypothesis.

But now for the spot λ of June 2, 1886. This was also a remarkably symmetrical one, of a large size, and specially adapted to the investigation in hand. On June 1 the spot was, at $5^h\ 30^m$ P.M., just one minute from the western limb, yet there was not the slightest appearance of any foreshortening of the *inner* side of the penumbra. In fact, if there was a difference, the advantage was by about 1″ or so on the *inner* side. The spot now subtended about 45″ in length, by about 17″ in breadth.

On June 2 (the day on which I had invited Mr. Ranyard, and also again Mr. Perry, to specially watch for Wilson's phenomenon) I made these notes: At $7^h\ 50^m$ A.M. the outer border of the penumbra of the spot λ was just 20″ from the western limb. The whole spot subtended 45″ in length of heliographical latitude, but so foreshortened in directions of longitude as to subtend not more than 10″ in width.

The *umbra* was as nearly as possible central, and having an apparent width of 3″. Both the preceding and following sides of the penumbra were of the same width, viz. 3″, though if there were a difference, the "following," or *inner*, side was the wider of the two, by perhaps 0″·5. There was at least a *sensible* difference (though exceedingly small, truly) in the opinion both of myself and a perfectly impartial fellow-observer, who, in fact, did not know what was expected one way or the other.

I regret that there should have been any divergence of opinion between Father Perry on the one side and Mr. Ranyard and myself on the other, though that divergence is evidently

extremely slight. What we require, however, in such investigations are actual measurements by micrometrical appliances.

Since writing the above I have carefully looked over the four last volumes of my drawings of solar spots, deposited in the library of our Society, extending over a period of ten years, from 1864 to 1873 inclusive, and find that during that period, whilst there are eleven instances fairly adverse to any phenomena of the foreshortening in question, there are seven instances fairly in its favour, but generally only to a slight degree.

With regard, however, to the very marked divergence between Dr. Wilson's observations of the last century and those of both Mr. Ranyard, Father Perry, and myself on this present occasion, we shall probably come to the conclusion that there are different classes of spots, and which, amongst other peculiarities, manifest very different degrees of profundity, as well as of general form, permanency, and even colour, as was observed in the month of April last by Mr. B. J. Hopkins, as well as on other occasions by Mr. Lockyer, myself, and, I doubt not, other observers.

Lastly, it may be as well to remember that the Sun's vastly deep and diaphanous atmosphere (whose existence is evinced by the very considerable diminution of the Sun's luminosity all round the margin of that luminary) must have some effect in modifying the appearances of all features situated on and near the limb. The effect of the refraction of the rays proceeding from the Sun's surface would be to cause somewhat more than half the disc to be visible to an observer on the Earth, and hence to retain solar features in sight which would otherwise have passed out of view; and also to flatten and level prominences standing on the limb, and possibly also to slightly increase the apparent width of the outer side of a penumbra somewhat more in proportion than the inner side, but from a different cause to that assigned to this by Dr. Wilson.

It was Professor Challis, I think, who many years ago drew attention to this modifying of objects on the Sun's limb, by virtue of the refraction exerted by the solar atmosphere.

The Fourth Satellite of Jupiter during Superior Conjunction on the Night of April 5, 1886. By Edmund J. Spitta.

A frequent explanation of the anomalous appearance which the satellites of *Jupiter* sometimes present during transit, but which is scarcely admitted to be adequate or satisfactory, is based upon the suggestion that the illumination of the hemisphere of the satellite then presented to the Earth is not equally distributed; and this explanation has been still further complicated by the suggestion that owing to the period of rotation possibly corresponding with that of revolution, this particular hemisphere is only seen at the time of transit, and that then the effect of the unequal illumination is aggravated by the contrast with the bright disk of *Jupiter*.

It seemed to me desirable, therefore, to call attention to the opportunity of examining the satellite at a time when the same hemisphere—neglecting libration—must necessarily be presented to the Earth as when the transit is in progress, and when the phenomenon would not be complicated by the background of *Jupiter's* disk, on which it is usually exhibited. Such opportunities of varying the condition under which the satellite can be seen occur but rarely, as a reference to the *Nautical Almanac* clearly shows, and I regret that the observations yet published have not been more numerous or definite. I present here those that have come under my own notice, or have been forwarded to me in consequence of the appeal I made to those interested in the subject.

All correspondents complain of the badness of the weather; hence my earliest note is at 8 P.M., when the satellite was to the north of its primary at its following limb. It was then bluish, and seemed scarcely brighter than the neighbouring portion of *Jupiter*. Mr. Denning thought it appeared as if veiled around its periphery and brighter at its centre. This was with his 10-inch Reflector; power, 252.

An hour later it was closer to *Jupiter*—almost touching it; it then appeared fainter than ever; and when compared with the nearest satellite, which was the first, it was found to reflect only one-fourth of the light of that satellite. (This observation was made, I am informed, with a photometer constructed after the plan suggested by Prof. Pritchard.) A friend and myself made our earliest observation at 10.30 P.M., and we both came to the conclusion that the size of the satellite appeared much reduced, and later still we thought its light was also diminished to about two-thirds of its usual quantity; but of course no definite allowance could be made for the effect of the adjacent luminary. I may add that I have witnessed a great number of transits of *Jupiter's* satellites, and since this observation have examined others, to note if the light of the other satellites when nearing transit was reduced as much as that of the fourth appeared to be at the time above mentioned, and I have come to the conclusion —however imperfect such eye-estimations may be—that they are not.

By a second photometric comparison between the light of the fourth with that of the first at 11.30 P.M. I am informed it was found that the reflected light had become increased, being then only one-third less than the comparison satellite; but whether this was due to the altered position of the satellite or to its reflective power having become greater, I am not in a position to state. Bad weather prevented any further observations either of the satellite or of its shadow.

Most observers reported fair definition. The instrument used here was the 10-inch Calver Reflector; power, 150.

Ivy House, Clapham Common,
1886, April.

Observations made at the U.S. Naval Observatory, Washington.

By Professor A. Hall, U.S.N.

(*Communicated by Commodore Geo. E. Belknap, U.S.N., Superintendent.*)

Conjunctions of the Satellites of Saturn.

Date.	Wash. M.T. h m	Pos.	Wt.	Remarks.
	Mimas.			
1886, Jan. 7	8 57·5	N	3	Excessively faint
Feb. 9	8 23·3	N	3	A little doubtful
	Enceladus.			
1885, Dec. 26	9 46·3	N	1	Very faint
1886, Feb. 23	7 34·3	N	3	
Mar. 10	9 15·5	N	3	
	Tethys.			
1885, Dec. 11	10 5·0	S	3	
12	8 53·6	N	3	
28	9 48·2	S	2	Cloudy
1886, Jan. 14	9 30·4	S	3	
15	7 58·0	N	3	
Feb. 1	7 38·5	N	3	Hazy
16	10 1·6	N	3	
17	8 44·4	S	3	Faint; hazy
18	7 26·7	N	—	
Mar. 5	9 43·9	N	2	
6	8 37·4	S	3	
7	7 7·9	N	3	
	Dione.			
1885, Dec. 11	9 37·0	S	3	
26	10 43·8	N	2	
1886, Jan. 6	9 16·4	N	2	
Feb. 1	9 5·9	S	3	
16	10 5·6	N	3	
Mar. 10	7 36·3	N	3	
14	10 19·8	S	2	
	Rhea.			
1885, Dec. 7	9 27·9	S	3	
16	10 12·8	S	4	
25	10 45·3	S	2	
1886, Feb. 15	8 23·5	N	2	Very unsteady
24	9 14·7	N	3	
Mar. 5	10 2·4	N	3	
14	10 59·0	N	2	

Satellites of Mars.

Deimos.

Date.	Wash. M.T.	P.	Wt.	Wash. M.T.	S.	Wt.	Remarks.
1886.	h m	°		h m	″		
Mar. 1	10 36·8	112·62	3	10 41·8	47·57	3	Windy; sat. faint
3	9 24·4	299·08	3	9 34·4	44·95	3	Very faint
4	12 12·4	283·05	3	12 20·9	47·75	3	Faint
4	12 31·4	283·58	3	12 38·4	48·19	3	
6	10 35·3	105 88	2	10 42·8	48·58	2	Very faint; sky misty

Comparison with Marth's Ephemeris.

	C − O.	
	Δp	Δs
	°	″
Mar. 1	−1·02	+0·05
3	−1 07	−0 36
4	−1·47	−1·42
4	−0·49	−1·14
6	−0·05	−0·49

Companion of Sirius.

Date.	Sid. Time.	P.	S.	Wt.	Remarks.
	h	°	″		
1886·180	5·5	30·7	7·11	3	Faint
·183	5·5	32·7	7 56	2	Very faint
·194	5·7	32 4	7·11	3	Faint
·202	6·1	33·5	7·75	2	Very faint
·273	8·0	29 5	7·38	2	Faint; 15 inches aperture; double weight
·295	8·6	28·1	7·40	2	Faint; 15 inches aperture; double weight

Mean Result.

	P	S
1886·221	30°·56	7″·39

Remarks.—The conjunctions of the satellites were observed by placing the wire of the micrometer perpendicular to the major axis of the ring by means of the angle of position given in the *American Ephemeris* for 1886, p. 481. The conjunction of *Mimas* on January 7 was observed by Lieut. W. H. Allen, U.S.N., and that of *Tethys* on February 18 by Mr. G. Anderson.

The satellites of *Mars* were very faint, this opposition being the most unfavourable that will happen between 1877 and 1892. The outer satellite could be observed fairly well, but the inner one was seen only once, and then it was so faint that no measurement was made. It appeared to be near the predicted place. The weather was very unfavourable. The elements of these

satellites are probably nearly correct, but the approaching oppositions will furnish better observations for correcting their motions. The preceding observations have been corrected for differential refraction. The correction for the figure of the planet is not sensible.

The companion of *Sirius* was very faint, and was a difficult object to observe. When the images were blazing it was found that the companion was seen better with the aperture reduced to fifteen inches. The last two observations were made with the smaller aperture, and they have been given double weight.

1886, *May* 5.

Observations of Fabry's Comet (*d.* 1885). By L. A. Eddie.

The recent abnormally clouded condition of our atmosphere, which has been attended by floods of rain and dense fogs, has prevented earlier observations of this comet, which was discovered on December 1 last by M. Fabry at Paris in the northern heavens, and which reached its perihelion about April 6, soon after which passage it was to reveal itself to star gazers in the southern hemisphere. This visitor was seen here for the first time on May 1, and was observed by myself with optical aid on May 2 from 6.30 to comet-set, about 7.40, when the head sunk below the western horizon. When first seen on this occasion it was about 18° above the western horizon, and was a very conspicuous object, with a head of tolerable brilliancy about 15′ in diameter, and possessing a broad tail widening out to about 1½°, and traceable to about 9° from the nucleus. It shone with a pale straw-coloured light, and the tail appeared perfectly straight without any sign of curvature, but sharply defined. It was situated in the constellation *Eridanus*, about 3° N.W. of *ν Eridani*, just beneath the well-known constellation *Orion*. The tail stretched upwards to a point about half way between *β Eridani* and *η Orionis*. When viewed through the telescope it revealed a bright and well-condensed nucleus, surrounded by a broad but less luminous coma, and conveyed the impression of a brilliant pellet well sunk in the midst of less luminous gas-jets, emitted by itself from around its periphery, which, after extending towards the Sun for a certain distance, were bent back upon themselves and streamed in the opposite direction, gradually widening out, and thus forming an elongated and truncated cone of extremely rare gaseous matter, with a ball of more condensed matter in its longitudinal axis, and situated at a short distance from the narrow extremity. A very small star, probably about the eighth magnitude, was seen through the coma close behind the nucleus, and another again a little higher up in the tail. The nucleus was eccentrically placed within the coma, and the striæ or hair-like nature of this latter was very

marked. The theoretical brightness of the comet now was about 500 times greater than when first discovered by Fabry.

May 3: cloudy and wet. Comet visible for a short interval only, and then indistinctly through misty clouds; it had moved about 9° to the east, and was now placed nearly half way between β and ψ *Eridani*. Nucleus appeared elongated; but this may be owing to the mist.

May 4: evening clear; comet about 7° higher than previous evening, but fading rapidly; could be detected by the naked eye a little before six o'clock. Tail could not be traced this evening further than 6° from the head, but seemed slightly curved, with the convex and more sharply defined margin on the south. It is now situated in the constellation *Lepus*, close to a sixth-magnitude star, near the tip of the ears of the hare. The nucleus, when viewed through the 9½-inch Calver, appeared very bright and condensed, and sharply defined, and of a ruddy brown colour, surrounded by a pale yellow coma of hyperbolic form, with its vertex almost pointed, and spreading out considerably in a lateral direction, so as to give the appearance of its possessing two luminous wings. The portion immediately behind the nucleus was comparatively dark, and the nucleus itself was more sharply defined on its eastern border; there was a considerable breadth of coma preceding the nucleus. The coma presented a granulated rather than a cometic appearance.

May 5: evening clear. Comet visible from 6 o'clock. Tail very faint, 5° in length. In 9½-inch Calver, nucleus very bright and sharply defined. There was a slight trace of the coma preceding the nucleus, forming two or three cometic envelopes of parabolic form; the lateral streams, as seen on the previous evening, were very faint. It was situated near ζ *Leporis*.

May 6: sky hazy, with thin cirri clouds. Comet very dim.; tail scarcely perceptible, about 4° in length. Nucleus in telescope dim, lateral streams not detectable. It was situated in *Lepus*, and a straight line drawn from α, through β *Canis Majoris*, and continued as far beyond β as this star is from α (*Sirius*), would mark almost the exact spot that the comet occupied at 7 o'clock.

May 7: sky hazy. Comet very faint. Tail about 2° in length. Not observable by telescope.

May 8: evening clear. Comet faintly visible, but tail scarcely discernible, being eclipsed by moonlight.

May 9 and May 10, clouded.

May 11: sky clear for short interval, moon very bright. Comet just discernible to the naked eye, situated in *Canis Major*, forming a right angle with ϵ and 22 *Canis*, about twice as far from ϵ as this star is from 22 *Canis*. When viewed through a 3½-inch Refractor appeared like a nebula slightly condensed in centre, and of ragged outline. In the 9½-inch Calver the nucleus shone brightly, and still retained the deep ruddy colour which is a distinguishing feature in this comet. This is the

first comet that I have observed whose nucleus has been of so deep a tint; the outlying coma is still a pale yellow.

May 12: comet very faint, only just distinguishable to unaided vision as a dim misty spot. It is now becoming a very insignificant object in the telescope, the background being so brilliantly illuminated by moonlight.

May 13: not observed.

May 14: comet invisible to naked eye. Moon very bright, easily found with finder. Has just entered the constellation *Argo Navis*. Nucleus still well condensed. No detectable change. Very mean object now.

Approximate Right Ascension and Declination at 7.30 P.M.

Date.	R.A.	South Dec.	Date.	R.A.	South Dec.
	h m	° ′		h m	° ′
May 2	4 22	1 30	May 7	6 15	22 0
3	5 12	6 0	8	6 28	24 30
4	5 20	12 0	11	7 4	29 30
5	5 37	15 0	12	7 15	30 15
6	5 54	19 15	14	7 24	33 30

Cape of Good Hope, Graham's Town.

Sextant Observations of Fabry's Comet.

(*Communicated by Captain H. Toynbee.*)

Observations made on board the barque "Viola," by Captain J. H. Price.

1886, May 2, 7.20 P.M. ($10^h\ 5^m\ 4^s$ G.M.T.) Lat. 16° 24′ N.; Long. 35° 31′ W. Comet's position was as follows:

	° ′
Nucleus to *Betelgeuse*	20 5
„ „ *Rigel*	10 20

Tail about 5° in length.

Observations made on board the H.M.S. "Spartan," by Captain A. McLean Wait.

1886, May 4, 8 P.M. ($8^h\ 45^m\ 55^s$ G.M.T.) Lat. 1° 54′ S.; Long. 12° 20′ W. Barometer 30·138. Thermometer, wet bulb 78°, dry bulb 85°. Comet's position was as follows:—

	° ′
Nucleus to *Betelgeuse*	20 35
„ „ *Sirius*	19 30

Altitude of nucleus 11°. Tail about 2° long, like a partially closed fan. Brightness about equal to a second-magnitude star.

Observations made on board the ship "Melbourne," by Captain C. F. Cooke.

1886, May 2, $9^h\ 11^m$ G.M.T., $7^h\ 30^m$ A.T.S.; D.R. Lat. 1° 20′ S.; D.R. Long. 25° 20′ W.

Distance of Comet from *Betelgeuse*	...	20°	9′
„ „ „ *Sirius*	... ...	34	1 30
Altitude	... ...	4	30

May 3, $8^h\ 50^m$ G.M.T., $7^h\ 4^m$ A.T.S.; D.R. Lat. 0° 43′ S.; D.R. Long. 26° 36′ W.

Distance of Comet from *Betelgeuse*	...	18°	58′
„ „ „ *Sirius*	... ...	26	28

May 5, $9^h\ 26^m$ G.M.T., $7^h\ 30^m$ A.T.S.; D.R. Lat. 1° 14′ N.; D.R. Long. 27° 20′ W.

Distance of Comet from *Betelgeuse*	... ...	23°	36′
„ „ „ *Sirius*	... ...	14	0

May 7, $9^h\ 8^m$ G.M.T., $7^h\ 20^m$ A.T.S.; D.R. Lat. 3° 44′ N.; D.R. Long. $28^h\ 22'$ W. Comet very faint. Observed through ordinary telescope; tail very short, large illuminated space round nucleus, which has always appeared larger than any comet I have ever seen before.

Observed angles with *Sirius*	... ...	° 26′
„ „ „ *Procyon*	... ...	33 50
„ „ „ *Canopus*	... ...	29 18

Observations of Comet a 1886 (*Brooks*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East or Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of Declination.

Comet a 1886.

	Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Par. and Refract. in R.A.	☄ − ✱ N.P.D.	Corr. for Par. and Refract. in N.P.D.	No. of Comp.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1886.	h m s		m s	s	′ ″	″		h m s	° ′ ″	
May 20	10 3 26	H.	−0 8·37	+0·21	−12 6·9	−18·8	3	2 43 53·30	45 12 29·2	*a*
	10 26 20		+0 36·37	+0·08	− 4 59·9	−12·5	3	2 44 5·62	45 13 6·7	*b*
	10 40 17		+2 22·30	+0·02	+ 0 53·9	− 6·1	2	2 44 8·58	45 13 49·9	*c*

Mean Places of Comparison Stars.

Star's Name.	R.A. 1886·0.	N.P.D. 1886·0.	Authority.
	h m s	° ′ ″	
(*a*) W.B. (2) II. 1016	2 44 1·74	45 24 44·9	Weisse's Bessel (2)
(*b*) Lalande 5203	2 43 29·45	45 18 9·2	Lalande
(*c*) W.B. (2) II. 961	2 41 46·54	45 12 52·0	Weisse's Bessel (2)

The observations are corrected for parallax and refraction. The initial H. is that of Mr. Hollis.

Royal Observatory, Greenwich:
1886, *June* 9.

Note with respect to the Invention of the Achromatic Telescope.

By A. C. Ranyard.

At a recent meeting of the Astronomical Society I mentioned that there was no account to be found in the Law Reports of the time of the action brought in 1766 by Peter Dollond, the son of John Dollond, against Champness, an optician in Cornhill, for infringing John Dollond's patent for making achromatic telescopes. The importance of any contemporary reference to this action arises from the fact that Champness, in his defence, proved to the satisfaction of Lord Mansfield that achromatic telescopes had been made by Mr. Moor Hall in 1733, that is, twenty-five years previously to the date of John Dollond's patent. It is known* that evidence was given by workmen who had been employed by Mr. Moor Hall to make achromatic lenses for him, but it is not known whether the workmen actually came into Court and were cross-examined, or whether their evidence was given by affidavit.

Mr. C. T. Martin saw a report of the discussion at the Astronomical Society's meeting, and wrote to suggest to me that I should search the Common Law Judgment Rolls preserved in the Record Office. I was under the impression that the action had been tried in the Court of King's Bench; for we know from subsequent references to the case that it was tried before Lord Mansfield, who was Chief Justice of the King's Bench, from the date of his appointment in November 1756 on till 1788. There is in the library of the Record Office a complete index of the actions tried during this period in the Courts of King's Bench and Common Pleas. I therefore searched the index of cases in the King's Bench for the names Dollond and Champness, but with no success, and I was about to give up the search, when the librarian suggested to me that Lord Mansfield might have sat to relieve a judge in another Court, and he suggested that I should search the index of cases in the Court of Common Pleas. There I found in the list of actions tried in the Easter Term of the seventh year of George III. the entry:—

> *James Chumpneys*, late of London, optician, to answer Peter Dollond, administrator of John Dollond. Damages £204. H. 6 Geo. III. 626 Middx.

The latter figures refer to the record of Judgments. On sending for the Judgment Roll for the Easter Term of 7th Geo. III. I found that Judgments numbered 622 to 627 were missing, and on searching through the file of affidavits made in the Common Pleas in Easter Term of 7th Geo. III. I was

* For references with respect to this evidence see *Astronomical Register* for 1881, pp. 196, 197.

unable to find any referring to the matter. The next day, on turning to the short notice of the decision given in the *Gentleman's Magazine* for 1766, p. 102, I found that judgment was given on Tuesday, February 18, 1766, which would correspond to the 6th year Geo. III., and I concluded that I must have made a mistake of a year in the index reference in the Record Office library. On sending for the Judgment Roll for Hilary Term of 6th Geo. III. I found that, by a curious coincidence, Judgments 622 to 627 were again missing. There seems to be no connection between the two Rolls. The librarian informed me that at that period registration of judgments was not compulsory, and as a small fee was charged for registration, several of the judgments—perhaps one in five—are missing.

By the courtesy of Mr. Selby, the Chief Librarian, I was allowed to have all the Common Pleas documents, consisting of *posteas* and *affidavits* for the years 1765, 1766, and 1767, in a private room to search at my leisure. The search occupied some days, as there were nine sacks full of *posteas*, and I went through all the affidavits without trusting to the rough alphabetical arrangement in which they have been stored. But I found nothing referring to the case of Dollond *v.* Champness. I was, however, rewarded by finding affidavits in two other actions brought by Peter Dollond against opticians to recover damages for infringing his father's patent. These actions seem to have been brought subsequently to the test case against Champness, or Chumpneys, and to have been settled as a matter of course. The affidavits only refer to formal matters connected with the service of writs, but they serve to show that at least three opticians besides James Champness had acted on the supposition that Dollond's patent would not be upheld.

Before judgment was given in Dollond *v.* Champness, Peter Dollond had commenced an action against Francis Watkins and Addison Smith as joint defendants. They are described as both of St. Martin's Lane, opticians. Subsequently Peter Dollond commenced an action against Henry Pyefinch, who is described as an optician of Cornhill. The affidavits in the first of these actions will be found filed under 'Dollond' in Easter Term of 6th Geo. III., and an affidavit in the second action under 'Dollond' in Michaelmas Term of 8th Geo. III. In both actions Messrs. Edmonson and Potts, of Bury Street, acted as attorneys for Peter Dollond. They were therefore probably the attorneys for Dollond in his action against Champness. The fact is worth noting, as papers connected with the case may have been preserved by the firm. A member of Mr. Dollond's family informed me some years ago that he had made inquiries, and believed that no papers referring to the case had been preserved by the Dollonds.

On the Superiority of Zinc and Steel Pendulums.

By Thomas Buckney.

At the last meeting of the Royal Astronomical Society, Dr. Leonard Waldo, of Yale College, U.S.A., was good enough to give us an account of certain improvements in astronomical clocks, or, as he preferred to call them, "clocks of precision." The net result of these improvements was stated to be a reduction of about 25 per cent. in the average errors of clock rates, and this as compared with the best previously existing clocks. This, if substantiated, would be a most important gain; but, unfortunately, Dr. Waldo gave us no figures in support of his statement, which, therefore, goes for nothing more than a mere expression of his own individual opinion. Now I cannot help thinking that when a statement of this kind is made to such a Society as this, it ought, to have any value, to be accompanied by the data on which it is founded, so that anyone interested in the matter may be able to weigh the facts and verify the deductions made from them. In the absence of such data we can only discuss the methods adopted, and endeavour to satisfy our own minds that they would probably produce the result said to be attained.

Now, the Yale clock or clocks which appear to have been constructed under Dr. Waldo's direction embody the following features, and it is to them that he attributes their excellent performance. They have:

1st. A heavy mercurial pendulum, the mercury weighing from 45 to 60 lbs. The jars containing the mercury and the pendulum rods are of steel.

2nd. The suspension of the pendulum is on a knife-edge, in lieu of the spring commonly used.

3rd. The escapement is a modification which is stated to be an improvement of one of the forms of Denison's Gravity Escapement.

4th. The support of the pendulum is a massive iron arch spanning two piers of masonry similar to the piers of a transit instrument, and it is between these piers that the pendulum swings. The clock movement is supported on a bracket placed between the piers, around which some arrangement of steam pipes is introduced for the purpose of regulating the temperature.

Well, now, the first thing that crosses one's mind is that some of these improvements are old acquaintances. Let us see, therefore, what is known about them, taking each one in the order already given. In order not to weary you I will, if possible, confine my references to one little book, which, although it has run through several editions and was written by a gentleman who is a Fellow of this Society, Dr. Waldo must, I think, imagine that few of us have seen. Perhaps Dr. Waldo himself

has not seen it, in which case I commend it to his notice, as the author, who is President of the British Horological Institute, is generally recognised as an authority on these matters. It is entitled "A Rudimentary Treatise on Clocks, Watches, and Bells," and I refer to it to prove that heavy mercurial pendulums, such as Dr. Waldo recommends, have been in use for many years. For in an edition of the work published in 1874 the author says, "In 1863 I had to calculate the height (that is, of the mercury) for the iron jar of a pendulum intended to weigh 40 lbs." Besides, there is on the Water Clock used for driving the Greenwich Equatorial, a mercurial pendulum of about this weight, which was made by my own predecessors probably thirty years ago. The jars of these pendulums were of iron it is true, but this is a point which is absolutely immaterial.

Now as to the knife-edge suspension. In a still older edition of this same rudimentary treatise—one published in 1850—I find it stated, "Occasional mention may be seen in books of pendulums vibrating for several hours on knife-edges—that is, on a suspension much like that of a scale beam. Such a suspension is the best for experiments to ascertain the undisturbed time of vibration due to gravity only, excluding the elasticity of a spring; but it is not to be inferred that it will answer in practice for a permanent pendulum of the proper weight for a clock, for even if the knife-edges and the planes on which they stand are made of the hardest stones, it is found that they soon suffer from the severe pressure, and introduce an amount of friction which is fatal to the accuracy of the pendulum." Well, since this condemnation, as far as I am aware, as regards clocks, the knife-edge suspension has remained dead and buried until Dr. Waldo dug it up and brought it as treasure-trove to our last meeting.

The modification made at Yale in the gravity escapement may or may not be an improvement. In either case it can have very little effect on the time-keeping of the clock, as it affects only the lifting of the arms by the clock train. As far as the pendulum, which is the time-measurer, is concerned, the escapement remains precisely what it was before the alteration.

I quite agree with the importance Dr. Waldo assigns to a rigid support for the pendulum. And here we are perfectly in accord with the author of the "Rudimentary Treatise," who points out its advantages in every edition of his work. There is a simpler and probably a better way of obtaining the desired rigidity—that is, by bolting a massive iron bracket to one of the main walls of the building in which the clock is to be placed, and hanging the pendulum from that; but it is obviously immaterial in which way the desired rigidity is obtained so that it be really secured. We now come to the last of Dr. Waldo's improvements—the introduction of steam piping round the piers on which his clock is fixed; and this certainly is a novel proposal. I will not, however, say any more about it, as I hope to be able to show that it is, or ought to be, quite unnecessary. But my purpose

in the present paper is not so much to show the antiquity of the novelties brought before us by Dr. Waldo as to show that they are not well calculated to yield the result he claims for them; and this more particularly applies to the pendulum, to which, as the time-measurer, I propose to confine myself. As it is possible that in what I am about to say I may repeat something I said at the last meeting, I must ask you to excuse me. Having had no idea that this subject was to be brought forward, I had no opportunity of referring to my memoranda bearing on it, and so was placed at a great disadvantage, as I had to speak entirely from memory. But the matter seems to me of sufficient importance to induce me to trespass on your time this evening, as I should be sorry to find Dr. Waldo's paper accepted as an accurate description of our knowledge as regards astronomical clocks.

Well, about eighteen years ago, it fell to my lot to make designs for four astronomical clocks, one of which was destined to become the sidereal standard clock of the Greenwich Observatory; the others were to be used as transit clocks in the British Transit of *Venus* Expeditions. The first of these clocks was by far the most important, and was to be constructed so as to embody the features of a specification drawn up by Sir George Airy. But the only point we have to consider here is the pendulum; which was to be a mercurial one. The other clocks were fitted with zinc and steel compensation pendulums, constructed in what was then the ordinary way; that is, the bobs, which were cylinders of lead, were supported at one end, so that the expansion or contraction of the bob itself entered into the compensation. These four clocks, completed at about the same time, were set going in a quiet room, in which there was a gas-stove, by which the temperature could be raised without difficulty to 90°. As set going under these circumstances, these clocks had a rather considerable temperature error; but what seemed at first rather curious was that this did not at first show itself in a very marked way, but kept on increasing for two or three days until the clocks finally settled down to a steady rate due to the higher temperature, and a similar sluggish action was noticed when the temperature was allowed to run down. It became evident that this sluggish action was due to the more slender parts of the pendulum (the rods and spring) taking up the new temperature very quickly, whilst the bobs, being much more bulky, required a much longer time to do this. I would here mention that, fully recognising the advantage of a heavy pendulum, I had given the Greenwich clock a jar $2\frac{3}{4}$ inches internal diameter, holding about 20 lbs. of mercury, the diameter of the jars in ordinary use being 2 inches, which would hold about 12 lbs. of mercury. Considering the matter, it occurred to me that if we were to eliminate from the compensative action of the zinc and steel pendulums the expansion of the bob, which we could easily do by suspending it at its centre of gravity, and rely entirely on the zinc and steel tubes and rod, matters would

be very much improved, as then the compensation would be effected by parts having pretty much the same bulk, and therefore likely to act simultaneously. And so it turned out. These zinc and steel pendulums were reconstructed on the principle above indicated, and the clock rates became very soon all that could be wished. But the Greenwich clock could not be altered in this way, as in a mercurial pendulum the compensation is and must be effected entirely by the expansion of the bob, and there seemed no satisfactory way of increasing the rapidity of its action whilst maintaining its weight. In the end I determined to lay the matter before Sir George Airy, and request his sanction to the removal of the mercurial pendulum from the Greenwich clock, and the substitution in its place of a zinc and steel pendulum on the new principle. The change produced the same rapid and simultaneous action obtained in the other clocks, and has, I venture to think, been quite satisfactory. It was in this way that it came about that the Greenwich clock has a zinc and steel pendulum, instead of the mercurial one originally intended for it.

Some time after this, being desirous of investigating more fully this sluggish action of the mercurial pendulum, I made the two following experiments, which are rather interesting. I took an ordinary mercurial pendulum jar of two inches diameter, and, having removed the steel rod, I cemented in its place a glass tube and filled the top completely with mercury, and also the tube to about half of its height. I marked the height of the mercury in the tube, and noted the temperature, which was about 60°. I then plunged the pendulum into hot water—temperature about 150°—and the result was as follows:

Almost immediately the mercury sunk in the tube considerably, but in less than a minute it began to expand with the heat, and then rose rapidly. The first effect of a sudden rise in the temperature was, however, to make the mercury fall—a phenomenon due evidently to the expansion of the jar by the sudden rise of temperature taking place before this new temperature was felt by the mercury to a sufficient extent to counteract it. This experiment, which was repeated several times with the same result, shows that the first effect of a change of temperature on a mercurial pendulum is in the inverse direction, and aggravates the error it is intended to correct. This goes on, although gradually lessening, until the mercury acquires the new temperature. But before this happens, an error has arisen which cannot be corrected; it may be, however, and probably is in many instances, masked by over-compensation. In any case irregularities of rate are engendered.

The next experiment was made as follows:

Two mercurial pendulum jars were taken, one of 2 inches diameter, and the other $2\frac{3}{4}$ inches diameter, the latter being the one discarded from the Greenwich clock. These were filled with mercury to about the height that would be required to com-

pensate the pendulums. In the place of the pendulum rods thermometers were inserted, the bulbs of which were plunged into the centre of the mercury and so arranged as to project above the caps of the jars to such a height as to allow the temperature to be read off. Similarly, a short length of the outer steel tube of a zinc and steel pendulum was taken, the lower end being stopped by a cork. Inside this was placed a short length of the zinc tube, and inside this, in lieu of the steel rod, was a thermometer as in the mercurial jars. A large saucepan was then obtained from the kitchen, and having adjusted the bobs and compensating piece of zinc and steel on a piece of non-conducting material in the bottom of the saucepan, water was put in until it nearly reached the top of the bobs. The saucepan was then placed on a gas-stove and the temperature raised to about 200°, and the whole kept in this state for a couple of hours, by which time the high temperature had thoroughly pervaded the masses of metal, as was shown by the readings of the thermometers. The bobs were then removed from the water and placed at a certain distance apart in a quiet room, the temperature of which was about 60°. Now, the object of this experiment was to ascertain how long each of these pendulums took to adapt itself to a new temperature; and the three thermometers were therefore watched, and the time each one took to cool down a certain number of degrees was noted.

Well, then, to cool down from 180° to 140° the zinc and steel pendulum took 4 minutes; the 2-inch mercurial one 21 minutes, and the 2¾-inch mercurial 29½ minutes. To cool from 140° to 120° the times occupied were respectively 5, 15, and 22½ minutes; from 120° to 100°, 8, 24, and 38 minutes; from 100° to 90°, 5, 19, and 29 minutes; from 90° to 80°, 8½, 28, and 49 minutes; and from 80° to 70°, below which point the observations were not carried, the times were 26½, 70, and 115 minutes. And the times respectively over the whole range of the experiment—that is, from 180° to 70°—were 57, 177, and 283 minutes.

The importance of these results will be more apparent and better appreciated if arranged in a table, as follows:

Temperature.	180° to 140°	140° to 120°	120° to 100°	100° to 90°	90° to 80°	80° to 70°	180° to 70°	Ratios
Zinc and Steel	4	5	8	5	8½	26½	37	1
2-inch Mercurial	21	15	24	19	28	70	177	3
2¾-inch Mercurial	29½	22½	38	29	49	115	283	5

Now, this experiment, to my mind, shows clearly that in any given change of temperature a zinc and steel pendulum in the compensating action of which the bob has no share is three times as rapid as a mercurial pendulum with a 2-inch jar, and five times as rapid as one with a 2¾-inch jar, and the clock errors would be in the proportion indicated by these figures. Indeed, it is certain that the zinc and steel pendulum would in

practice show even better than it did here; because in these pendulums the steel tube is cut through so as to expose nearly the whole of the zinc tube, and this latter is pierced with many holes to allow the temperature to reach the inner rod, whereas in this experiment the tubes were entire. As regards the two mercurial pendulums, it will be seen, as might have been suspected, that the larger one took longer to cool than the smaller, although possibly one would not have thought that the difference would be so great. It seems to vary rather more quickly than the area, but this may be due to some difference in the thickness of the walls of the two jars. Let us, therefore, assume that the sluggishness varies as the area, and see how the large bobs containing 45 and 60 lbs. of mercury, recommended by Dr. Waldo, would come out. These would have an internal diameter of four and five inches approximately, and the areas would be as follows:

Diameter	2	$2\frac{1}{4}$	4	5
Areas	3·14	5·93	12·56	19·63

If, therefore, my experiment holds good for these larger diameters (and I do not see why it should not do so), Dr. Waldo would find that his 4-inch pendulum would take $12\frac{1}{2}$ times as long as the zinc and steel one, and his 5-inch pendulum 20 times as long, to adapt themselves to a new temperature, and as compared with the 2-inch pendulum in common use they would be 4 and $6\frac{1}{2}$ times as long. And it will be evident that the more the size of the jar is increased the greater the error will be. In fact, of mercurial pendulums it may be said the bigger they are the worse they are. The errors of Dr. Waldo's clocks, due to the sluggish action of his large pendulums, may, no doubt, be lessened by a careful manipulation of his steam pipes; but clocks cannot always be treated as exotics: we want something more hardy. I would urge most strenuously the importance of protecting clocks from sudden and great changes of temperature. It is, indeed, absolutely necessary that this should be done, and if a dry underground chamber can be found and a clock set up in such a place, where only gradual variations of temperature occur, one may reasonably look for a good performance. But such protection cannot always be found, and in order to prove that a zinc and steel pendulum can, and does, give a good result under very trying circumstances, I cannot do better than append the following rates of one of the three clocks referred to in the earlier part of this paper. These rates were taken for a period of six months, from September 3, 1871, to March 21, 1872, during which time the clock was going in one of the little huts prepared for the Transit of *Venus* Expedition, erected in the grounds of the Royal Observatory, and are extracted from the official records of that Institution.

Royal Observatory, Greenwich.

Errors and Rates of the Clock "Dent" 1914, on Greenwich Sidereal Time.

Date.	Clock slow.	Mean daily losing rate during each interval.	Average temperature of external air.	Extremes of temperature of external air.
	d h m s	s	°	° °
1871 Sept. 3	21·7 14 31·8	4·45	61	79–47
17	21·5 15 34·1	4·02	52	68–39
24	21·8 16 2·3	4·54	51	66–42
Oct. 1	22·6 16 34·2	4·43	51	65–40
8	21·9 17 5·1	4·55	46	60–31
15	21·6 17 36·9	4·47	54	68–41
22	21·6 18 8·2	4·24	47	59–33
29	21·3 18 37·8	4·25	46	55–35
Nov. 5	22·7 19 7·8	4·07	38	50–26
12	22·2 19 36·2	4·24	35	51–20
19	21·7 20 5·8	4·36	36	44–28
26	21·7 20 36·3	4·33	36	43–28
Dec. 3	22·2 21 6·7	3·89	30	40–19
10	21·9 21 33·9	4·67	41	47–27
17	21·8 22 6·6	4·77	42	49–35
26	0·1 22 45·2	4·74	43	48–33
31	21·9 23 13·2	4·72	42	51–34
1872 Jan. 7	22·3 23 46·3	4·93	40	51–32
14	21·6 24 20·7	4·79	39	48–28
21	21·6 24 54·2	5·13	42	51–36
28	22·1 25 30·2	5·17	45	54–37
Feb. 4	22·1 26 6·4	5·00	47	58–33
11	22·2 26 41·4	4·96	44	54–37
18	21·7 27 16·0	4·85	45	56–35
25	21·8 27 50·0	4·88	46	58–32
Mar. 3	21·6 28 24·1	4·86	47	61–28
10	21·6 28 58·1	4·73	46	59–28
17	21·4 29 31·2			

During the whole time of rating, the clock was situated in one of the small Observatories intended for use in the observations of the Transit of *Venus*, 1874. No record of the temperature of the hut was kept, but its temperature would be nearly the same as that of the external air.

But our experience of these zinc and steel pendulums is not limited to these four clocks. There are three in use in the Royal Observatory, Greenwich, and others fitted with these pendulums will be found at the Observatories of Brussels, Liège, Copenhagen, San Fernando, Coimbra, Lisbon, Tokio, Hongkong, Cape of Good Hope, Port Elizabeth, and at many others; but these will suffice to show that they really do work well. A further improvement has recently been introduced, which allows an alteration in the compensation to be made by the astronomer without the slightest difficulty, and this without making a very wide difference in the clocks' rate; thus removing the possible objection that such an alteration could only be made by a clockmaker. I hope to bring this before you at some future time. As it is, I fear I have already detained you much too long. But I wished to show you that Dr. Waldo's novelties are not new, and that they are not likely to realise his expectations. I wished to point out the defects of the large mercurial pendulums he recommends; and I hope I have made it clear that, in a variable temperature, these pendulums do not and cannot act with the rapidity that is necessary. In order to maintain a steady rate, it is essential that the length of the pendulum—that is, the distance between the point of suspension and the centre of oscillation—shall, under all circumstances, be unaltered; a result which cannot be obtained with a pendulum, one part of which is affected by a change of temperature before the other part. If, then, my experiments are to be relied on, the conclusion must be drawn that the zinc and steel pendulum much more nearly fulfils the condition of simultaneous action, and is for this reason to be preferred. And this conclusion is justified by actual experience.

Ephemerides of the Satellites of Saturn, 1886–87. By A. Marth.

The five inner satellites deviate so little from the plane of the ring that their deviations are most suitably treated as latitudes above this plane, the ascending node N and inclination I of which, in reference to the plane of the Earth's equator, are here assumed to be

for 1887·0 $\quad N = 126°·5896 \quad I = 6°·9973$

The assumed longitudes of the five satellites in their orbits (i.e. their longitudes from the ascending node added to the Right Ascension N of the ascending node, reckoned from the point of the true equinox), referred to the time when the light arrives at the distance [0·950], are the following:

Greenwich Noon.	Mimas.	Enceladus.	Tethys.	Dione.	Rhea.
	°	°	°	°	°
1886, Oct. 10	0·183	180·228	158·187	272·596	35·843
Nov. 9	299·954	142·184	119·132	258·647	266·548
Dec. 9	239·726	104·141	80·076	244·699	137·252
1887, Jan. 8	179·499	66·098	41·021	230·751	7·957
Feb. 7	119·273	28·055	1·966	216·803	238·662
Mar. 9	59·048	350·011	322·910	202·854	109·366
Apr. 8	358·824	311·968	283·854	188·906	340·070
May 8	298·601	273·924	244·798	174·957	210·774

The adopted daily sidereal motions of the five satellites and the corresponding periods of their sidereal revolutions are:

	°	d h m s
Mimas	381·99243	0 22 37 5·70
Enceladus ...	262·73186	1 8 53 6·86
Tethys	190·69812	1 21 18 25·96
Dione	131·53503	2 17 41 9·33
Rhea	79·69012	4 12 25 11·87

The values for *Mimas* belong to 1887, Jan. 8, and depend on the hypothesis of accelerated motion.

In the following tables P denotes the position-angle of the minor axis of the ring, L+180° the planetocentric longitude of the Earth referred to the plane of the ring, Λ+180° that of the Sun, or Λ−L the difference between the two. The apparent equatorial diameter of the ball and the diameter of the outer rim of the ring depend still on Bessel's determinations. The assumed proportion of the polar axis of the ball to the equatorial diameter is 0·900.

In the tables for the satellites a and b are the semi-axes of the apparent orbits, l−L the longitudes of the satellites in their orbits, reckoned from the points which are in superior conjunction with the planet's centre or in opposition to the Earth in longitude. By adding to l−L the value of L from the first table, the longitudes l are found.

The values of P, a, b, and l−L are to be interpolated directly for the times for which the apparent positions of the satellites are required, the equation of light being already taken into account in the given values, and the rectangular co-ordinates x and y, reckoned parallel to the axes of the ring and expressed in seconds of arc, or, if polar co-ordinates are wanted, the position-angles p and distances s of the satellites in reference to the centre of the planet are then found by means of the equations

$$s \sin (p - \mathrm{P}) = x = a \sin (l - \mathrm{L})$$
$$s \cos (p - \mathrm{P}) = y = b \cos (l - \mathrm{L}).$$

Greenwich Noon.	P	L	Latitude of Earth above plane of ring.	Latitude of Sun above plane of ring.	A−L.
1886.					
Sept. 30	352°·608	115°·925	−22°·895	−24°·491	−6°·502
Oct. 5	·602	116·217	22·819	24·455	6·594
10	·598	116·472	22·755	24·418	6·648
15	·595	116·684	22·703	24·381	6·659
20	·592	116·849	22·663	24·344	6·624
25	·590	116·966	22·636	24·306	6·541
30	·589	117·035	22·623	24·268	6·409
Nov. 4	352·588	117·055	−22·624	−24·230	−6·229
9	·588	117·026	22·639	24·192	6·000
14	·589	116·949	22·667	24·154	5·723
19	·591	116·825	22·708	24·115	5·400
24	·593	116·655	22·762	24·076	5·030
29	·596	116·440	22·829	24·036	4·615
Dec. 4	352·600	116·183	−22·907	−23·997	−4·159
9	·605	115·887	22·996	23·956	3·664
14	·610	115·557	23·092	23·917	3·135
19	·616	115·196	23·196	23·877	2·576
24	·623	114·810	23·306	23·836	1·991
29	·631	114·403	23·421	23·795	1·385
1887.					
Jan. 3	352·640	113·981	−23·539	−23·754	−0·765
8	·649	113·552	23·658	23·713	−0·138
13	·659	113·121	23·776	23·671	+0·491
18	·669	112·694	23·891	23 629	1·117
23	·679	112·277	24·003	23·587	1·732
28	·689	111·876	24·110	23·545	2·330
Feb. 2	352·699	111·497	−24·210	−23·502	+2·906
7	·709	111·147	24·303	23·459	3·453
12	·718	110·829	24·387	23·416	3·968
17	·726	110·548	24·462	23·373	4·446
22	·733	110·308	24·527	23·329	4·883
27	·739	110 111	24·582	23·285	5·277
Mar. 4	352·744	109·960	−24·626	−23·241	+5·624
9	·747	109·857	24·658	23·197	5·923
14	·748	109·803	24·679	23·153	6·173
19	·747	109·799	24·689	23·108	6·374
24	·745	109·844	24·688	23·063	6·525
29	·742	109·938	24·676	23·018	6·626

Greenwich Noon.	P	L	Latitude of Earth above plane of ring.	Latitude of Sun above plane of ring.	A−L.
1887.	°	°	°	°	°
Apr. 3	352·737	110·081	−24·653	−22·972	+6·678
8	·731	110·271	24·618	22·926	6·684
13	·723	110·507	24·572	22·880	6·644
18	·714	110·786	24·516	22·834	6·560
23	·704	111·107	24·449	22·788	6·434
28	·693	111·469	24·372	22·741	6·267
May 3	352·682	111·868	−24·285	−22·694	+6·063
8	·670	112·301	24·188	22·647	5·824
13	·658	112·767	24·081	22·600	5·552
18	352·645	113·264	−23·965	−22·552	+5·250

Greenwich Noon.	Diameter of Ball. Equat.	Phase	Polar prec. *l*.	Axis of Ring. Major	Minor	a_1	*Mimas.* b_1	l_1-L.	Diff.
1886.	″	″	″	″	″	″	″	°	°
Sept. 30	17·63	0·057	16·14	40·64	15·81	27·76	−10·80	23·63	1909·85
Oct. 5	17·78	·059	16·29	41·00	15·90	28·01	10·86	133·48	·89
10	17·94	·060	16·43	41·37	16·00	28·26	10·93	243·37	·93
15	18·11	·061	16·58	41·75	16·11	28·52	11·01	353·30	1909·98
20	18·28	·061	16·73	42·14	16·23	28·79	11·09	103·28	1910·02
25	18·45	·060	16·89	42·53	16·37	29·05	11·18	213·30	·07
30	18·62	·058	17·05	42·92	16·51	29·32	11·28	323·37	·12
Nov. 4	18·79	·055	17·20	43·31	16·66	29·59	−11·38	73·49	1910·16
9	18·96	·052	17·35	43·70	16·82	29·86	11·49	183·65	·20
14	19·12	·048	17·50	44·08	16·99	30·11	11·60	293·85	·24
19	19·28	·043	17·65	44·44	17·16	30·36	11·72	44·09	·28
24	19·43	·038	17·79	44·79	17·33	30·60	11·84	154·37	·31
29	19·57	·032	17·92	45·12	17·50	30·83	11·96	264·68	·34
Dec. 4	19·70	·026	18·04	45·42	17·68	31·03	−12·08	15·02	1910·37
9	19·82	·020	18·15	45·69	17·85	31·22	12·20	125·39	·39
14	19·92	·015	18·25	45·93	18·01	31·38	12·31	235·78	·40
19	20·01	·010	18·34	46·13	18·17	31·52	12·42	346·18	·41
24	20·08	·006	18·41	46·30	18·32	31·63	12·52	96·59	·41
29	20·14	·003	18·46	46·42	18·45	31·72	12·61	207·00	·41
1887.									
Jan. 3	20·17	0·001	18·49	46·50	18·57	31·77	−12·69	317·41	1910·41
8	20·18	follow.	18·50	46·53	18·67	31·79	12·76	67·82	·39
13	20·18	limb.	18·50	46·51	18·75	31·78	12·81	178·21	·36
18	20·15	0·002	18·48	46·45	18·81	31·74	12·85	288·57	·34
23	20·11	·005	18·44	46·35	18·85	31·67	12·88	38·91	·31
28	20·04	·008	18·39	46·20	18·87	31·57	12·89	149·22	·27

Greenwich Noon.	Diameter of Ball. Equat.	Phase	Polar foll. l.	Axis of Ring. Major	Minor	*Mimas.* a_1	b_1	$l_1-L.$	Diff.
1887.	″	″	″	″	″	″	″	°	°
Feb. 2	19·96	·013	18·32	46·01	18·87	31·44	−12·89	259·49	1910·22
7	19·86	·018	18·23	45·78	18·84	31·28	12·87	9·71	·17
12	19·75	·023	18·13	45·52	18·80	31·10	12·84	119·88	·13
17	19·62	·030	18·01	45·23	18·73	30·90	12·80	230·01	·08
22	19·48	·035	17·89	44·91	18·64	30·69	12·74	340·09	1910·02
27	19·33	·041	17·75	44·57	18·54	30·45	12·67	90·11	1909·96
Mar. 4	19·18	·046	17·61	44·21	18·42	30·21	−12·59	200·07	·90
9	19·02	·051	17·46	43·84	18·29	29·95	12·50	309·97	·85
14	18·85	·055	17·31	43·45	18·14	29·69	12·40	59·82	·80
19	18·68	·058	17·15	43·06	17·99	29·42	12·29	169·62	·74
24	18·51	·060	17·00	42·67	17·82	29·15	12·18	279·36	·69
29	18·34	·061	16·84	42·27	17·65	28·88	12·06	29·05	·63
Apr. 3	18·17	·061	16·68	41·88	17·47	28·62	−11·94	138·68	1909·59
8	18·00	·061	16·53	41·50	17·29	28·35	11·81	248·27	·55
13	17·84	·060	16·38	41·12	17·10	28·10	11·68	357·82	·50
18	17·68	·058	16·23	40·75	16·91	27·85	11·55	107·32	·46
23	17·53	·055	16·09	40·40	16·72	27·60	11·42	216·78	·43
28	17·38	·052	15·95	40·06	16·53	27·37	11·29	326·21	·40
May 3	17·24	·048	15·82	39·73	16·34	27·15	−11·17	75·61	1909·37
8	17·10	·044	15·69	39·43	16·15	26·94	11·04	184·98	·34
13	16·98	·040	15·57	39·14	15·97	26·74	10·91	294·32	1909·32
18	16·86	0·035	15·46	38·86	15·79	26·55	−10·79	43·64	

Greenwich Noon.	*Enceladus.* a_2	b_2	l_2-L	Diff.	*Tethys.* a_3	b_3	$l_3-L.$	Diff.
1886.	″	″	°	°	″	″	°	°
Sept. 30	35·62	−13·86	316·50	1313·49	44·09	−17·15	294·93	953·29
Oct. 5	35·93	13·94	189·99	·53	44·48	17·25	168·22	·33
10	36·26	14·02	63·52	·57	44·88	17·36	41·55	·37
15	36·59	14·12	297·09	·62	45·30	17·48	274·92	·41
20	36·93	14·23	170·71	·67	45·72	17·61	148·33	·46
25	37·27	14·35	44·38	·71	46·14	17·76	21·79	·51
30	37·62	14·47	278·09	·76	46·57	17·91	255·30	·56
Nov. 4	37·96	−14·60	151·85	1313·80	46·99	−18·08	128·86	953·61
9	38·30	14·74	25·65	·85	47·41	18·25	2·47	·65
14	38·63	14·89	259·50	·89	47·82	18·43	236·12	·69
19	38·95	15·04	133·39	·93	48·22	18·61	109·81	·73
24	39·26	15·19	7·32	1313·97	48·60	18·80	343·54	·77
29	39·55	15·34	241·29	1314·00	48·95	18·99	217·31	·81

Greenwich Noon. 1886.		a_s	b_s	l_s-L	Diff.	a_s	b_s	l_s-L	Diff.
		″	″	°	°	″	″	°	°
Dec.	4	39·81	−15·49	115·29	·03	49·28	−19·18	91·12	953·84
	9	40·05	15·64	349·32	·05	49·58	19·37	324·96	·87
	14	40·26	15·79	223·37	·08	49·84	19·55	198·83	·89
	19	40·44	15·93	97·45	·09	50·06	19·72	72·72	·91
	24	40·58	16·06	331·54	·09	50·23	19·87	306·63	·92
	29	40·69	16·17	205·63	·10	50·37	20·02	180·55	·93
1887.									
Jan.	3	40·75	−16·28	79·73	1314·10	50·45	−20·15	54·48	953·92
	8	40·78	16·36	313·83	·09	50·48	20·26	288·40	·92
	13	40·77	16·44	187·92	·07	50·47	20·35	162·32	·91
	18	40·71	16·49	61·99	·05	50·40	20·41	36·23	·89
	23	40·62	16·53	296·04	1314·02	50·29	20·46	270·12	·86
	28	40·49	16·54	170·06	1313·99	50·13	20·48	143·98	·83
Feb.	2	40·33	−16·54	44·05	·95	49·92	−20·47	17·81	953·80
	7	40·13	16·52	278·00	·90	49·68	20·44	251·61	·76
	12	39·90	16·48	151·90	·86	49·39	20·39	125·37	·71
	17	39·65	16·42	25·76	·81	49·08	20·32	359·08	·66
	22	39·37	16·34	259·57	·76	48·73	20·23	232·74	·62
	27	39·07	16·25	133·33	·71	48·36	20·12	106·36	·57
Mar.	4	38·75	−16·15	7·04	1313·65	47·97	−19·99	339·93	953·51
	9	38·42	16·03	240·69	·60	47·57	19·84	213·44	·46
	14	38·09	15·90	114·29	·55	47·15	19·69	86·90	·41
	19	37·75	15·77	347·84	·49	46·72	19·52	320·31	·36
	24	37·40	15·62	1·33	·44	46·30	19·34	193·67	·31
	29	37·05	15·47	94·77	·39	45·87	19·15	66·98	·26
Apr.	3	36·71	−15·31	328·16	1313·34	45·44	−18·96	300·24	953·20
	8	36·37	15·15	201·50	·30	45·03	18·76	173·44	·17
	13	36·04	14·99	74·80	·26	44·62	18·55	46·61	·12
	18	35·72	14·82	308·06	·21	44·22	18·35	279·73	·08
	23	35·41	14·66	181·27	·18	43·83	18·14	152·81	·04
	28	35·11	14·49	54·45	·15	43·46	17·94	25·85	953·01
May	3	34·83	−14·32	287·60	·11	43·11	−17·73	258·86	952·98
	8	34·56	14·16	160·71	·09	42·78	17·53	131·84	·95
	13	34·30	14·00	33·80	1313·06	42·46	17·33	4·79	952·91
	18	34·06	−13·84	266·86		42·17	−17·13	237·70	

Greenwich Noon.		*Dione.* a_4	b_4	l_4-L	Diff.	*Rhea.* a_8	b_8	l_8-L	Diff.
1886.		″	″	°	°	″	″	°	°
Sept.	30	56·47	−21·97	281·08	657·44	78·86	−30·68	202·87	398·19
Oct.	5	56·97	22·10	218·52	·49	79·56	30·86	241·06	·24
	10	57·48	22·24	156·01	·52	80·28	31·05	279·30	·28
	15	58·01	22·39	93·53	·57	81·01	31·27	317·58	·32
	20	58·55	22·56	31·10	·62	81·77	31·51	355·90	·37
	25	59·10	22·75	328·72	·67	82·53	31·76	34·27	·42
	30	59·64	22·94	266·39	·72	83·29	32·04	72·69	·47
Nov.	4	60·19	−23·15	204·11	657·76	84·05	−32·33	111·16	398·51
	9	60·72	23·37	141·87	·81	84·80	32·64	149·67	·56
	14	61·25	23·60	79·68	·85	85·53	32·96	188·23	·61
	19	61·76	23·84	17·53	·89	86·24	33·29	226·84	·65
	24	62·24	24·08	315·42	·94	86·92	33·63	265·49	·70
	29	62·70	24·32	253·36	657·98	87·55	33·97	304·19	·73
Dec.	4	63·22	−24·56	191·34	658·01	88·14	−34·31	342·92	398·77
	9	63·49	24·80	129·35	·04	88·67	34·64	21·69	·80
	14	63·83	25·03	67·39	·06	89·14	34·96	60·49	·83
	19	64·11	25·25	5·45	·08	89·53	35·26	99·32	·85
	24	64·34	25·45	303·53	·10	89·85	35·55	138·17	·86
	29	64·51	25·64	241·63		90·09	35·81	177·03	·88
1887.									
Jan.	3	64·61	−25·80	179·73	658·11	90·23	−36·04	315·91	398·88
	8	64·66	25·94	117·84	·10	90·29	36·23	254·79	·88
	13	64·64	26·06	55·94	·10	90·26	36·39	293·67	·88
	18	64·55	26·14	354·04	·08	90·15	36·51	332·55	·86
	23	64·41	26·20	292·12	·06	89·95	36·59	11·41	·84
	28	64·20	26·23	230·18	658·03	89·66	36·62	50·25	·81
Feb.	2	63·94	−26·22	168·21	657·99	89·29	−36·62	89·06	398·78
	7	63·62	26·18	106·20	·96	88·85	36·57	127·84	·75
	12	63·26	26·12	44·16	·91	88·34	36·48	166·59	·71
	17	62·86	26·03	342·07	·87	87·78	36·35	205·30	·66
	22	62·41	25·91	279·94	·83	87·16	36·18	243·96	·62
	27	61·94	25·77	217·77	·78	86·50	35·98	282·58	·57
Mar.	4	61·44	−25·60	155·55	657·72	85·80	−35·75	321·15	398·52
	9	60·92	25·42	93·27	·67	85·07	35·49	359·67	·47
	14	60·39	25·21	30·94	·62	84·33	35·21	38·14	·42
	19	59·84	25·00	328·56	·57	83·57	34·91	76·56	·37
	24	59·29	24·77	266·13	·52	82·80	34·59	114·93	·32
	29	58·75	24·53	203·65	·47	82·04	34·25	153·25	·27

Greenwich Noon.		*Dione.* a_4	b_4	l_4-L	Diff.	*Rhea.* a_5	b_5	l_5-L	Diff.
1887.		″	″	°	°	″	″	°	°
Apr.	3	58·20	−24·28	141·12	657·42	81·28	−33·90	191·52	398·22
	8	57·67	24·02	78·54	·38	80·53	33·55	229·74	·18
	13	57·14	23·76	15·92	·33	79·80	33·18	267·92	·13
	18	56·63	23·50	313·25	·29	79·09	32·82	306·05	·09
	23	56·14	23·24	250·54	·26	78·40	32·45	344·14	·06
	28	55·67	22·97	187·80	·22	77·74	32·08	22·20	398·02
May	3	55·22	−22·71	125·02	·18	77·11	−31·71	60·22	397·98
	8	54·79	22·45	62·20	·15	76·51	31·35	98·20	·95
	13	54·39	22·19	359·35	657·13	75·95	30·99	136·15	397·92
	18	54·01	−21·94	296·48		75·42	−30·63	174·07	

Approximate Greenwich Mean Times of conjunctions of the satellites with the centre of the planet.

"*n*" inferior conjunction with centre, or satellite exactly in the direction of the minor axis of the ring, north, moving from the following to the preceding side.

"*s*" superior conjunction, or satellite south, moving from the preceding to the following side.

Careful observations of the position-angles of the satellites at the times of these conjunctions afford the best means for determining the longitudes of the satellites in their orbits, and are least liable to systematic errors. It is very desirable that they should be regularly made, when they occur at convenient hours.

1886.	h			1886.	h			1886.	h		
Sept. 29	5·5	Di.	n.	Oct. 2	18·4	Mi.	s.	Oct. 5	15·5	En.	s.
	9·5	Te.	n.		21·7	En.	s.	6	0·1	Te.	s.
	17·1	Rh.	n.	3	4·2	Te.	n.		1·8	Di.	s.
30	8·2	Te.	s.		8·1	Di.	s.		8·0	En.	n.
	14·4	Di.	s.		14·2	En.	n.		11·8	Rh.	s.
	20·4	En.	n.		17·0	Mi.	s.		12·8	Mi.	s.
	21·1	Mi.	s.	4	2·8	Te.	s.		22·8	Te.	n.
Oct. 1	6·8	Te.	n.		5·6	Rh.	n.	7	10·7	Di.	n.
	12·9	En.	s.		15·6	Mi.	s.		11·5	Mi.	s.
	19·7	Mi.	s.		17·0	Di.	n.		16·9	En.	n.
	23·3	Di.	n.		23·1	En.	n.		21·5	Te.	s.
	23·3	Rh.	s.	5	1·5	Te.	n.	8	9·3	En.	s.
2	5·5	Te.	s.		14·2	Mi.	s.		18·1	Rh.	n.

1886.	h			1886.	h			1886.	h		
Oct. 8	19·5	Di.	s.	Oct. 18	9·5	Di.	n.	Oct. 28	16·4	Mi.	n.
	20·1	Te.	n.		16·0	En.	n.		22·6	Te.	s.
	21·4	Mi.	n.	19	5·3	Te.	s.	29	2·1	Rh.	s.
9	18·2	En.	s.		18·3	Di.	s.		8·2	Di.	n.
	18·8	Te.	s.	20	1·2	Rh.	s.		14·5	Te.	n.
	20·0	Mi.	n.		4·0	Te.	n.		15·0	Mi.	n.
10	4·4	Di.	n.		17·3	En.	s.		15·0	En.	n.
	10·6	En.	n.	21	2·6	Te.	s.	30	13·2	Te.	s.
	17·4	Te.	n.		3·2	Di.	n.		13·6	Mi.	n.
	18·6	Mi.	n.		9·7	En.	n.		17·1	Di.	s.
11	0·3	Rh.	s.		14·7	Mi.	s.		23·9	En.	n.
	13·2	Di.	s.	22	1·3	Te.	n.	31	8·3	Rh.	n.
	16·1	Te.	s.		7·5	Rh.	n.		11·8	Te.	n.
	17·2	Mi.	n.		12·0	Di.	s.		12·2	Mi.	n.
	19·5	En.	n.		13·4	Mi.	s.		16·4	En.	s.
12	12·0	En.	s.		18·6	En.	n.	Nov. 1	1·9	Di.	n.
	14·7	Te.	n.		23·9	Te.	s.		8·8	En.	n.
	15·9	Mi.	n.	23	11·1	En.	s.		10·5	Te.	s.
	22·1	Di.	n.		12·0	Mi.	s.		10·8	Mi.	n.
13	6·5	Rh.	n.		20·9	Di.	n.	2	9·1	Te.	n.
	13·4	Te.	s.		22·6	Te.	n.		10·8	Di.	s.
	14·5	Mi.	n.	24	10·6	Mi.	s.		14·5	Rh.	s.
	20·9	En.	s.		13·7	Rh.	s.		17·7	En.	n.
14	6·9	Di.	s.		19·9	En.	s.		20·8	Mi.	s.
	12·0	Te.	n.		21·3	Te.	s.	3	7·8	Te.	s.
	13·1	Mi.	n.	25	5·7	Di.	s.		10·1	En.	s.
	13·3	En.	n.		12·4	En.	n.		19·4	Mi.	s.
15	10·7	Te.	s.		19·9	Te.	n.		19·6	Di.	n.
	11·7	Mi.	n.		20·5	Mi.	n.	4	6·4	Te.	n.
	12·8	Rh.	s.	26	14·5	Di.	n.		18·0	Mi.	s.
	15·8	Di.	n.		18·6	Te.	s.		19·0	En.	s.
	22·2	En.	n.		19·1	Mi.	n.		20·7	Rh.	n.
16	9·4	Te.	n.		19·9	Rh.	n.	5	4·4	Di.	s.
	14·6	En.	s.		21·3	En.	n.		5·1	Te.	s.
	21·7	Mi.	s.	27	13·7	En.	s.		11·4	En.	n.
17	0·6	Di.	s.		17·2	Te.	n.		16·6	Mi.	s.
	8·0	Te.	s.		17·8	Mi.	n.	6	3·7	Te.	n.
	19·0	Rh.	n.		23·4	Di.	s.		13·3	Di.	n.
18	6·7	Te.	n.	28	15·9	Te.	s.		15·2	Mi.	s.

1886.	h			1886.	h			1886.	h		
Nov. 6	20·3	En.	n.	Nov. 17	12·0	Di.	n.	Nov. 27	1·8	Di.	s.
7	2·4	Te.	s.		19·4	En.	n.		9·5	En.	n.
	2·9	Rh.	s.	18	9·9	Rh.	n.		10·6	Rh.	n.
	12·8	En.	n.		10·2	Te.	s.		20·1	Mi.	n.
	13·9	Mi.	s.		11·8	En.	s.		20·7	Te.	s.
	22·1	Di.	s.		20·8	Di.	s.	28	10·6	Di.	n.
8	1·0	Te.	n.		21·2	Mi.	s.		18·4	En.	n.
	12·5	Mi.	s.	19	8·8	Te.	n.		18·7	Mi.	n.
	21·7	En.	s.		19·8	Mi.	s.		19·3	Te.	n.
	23·7	Te.	s.		20·7	En.	s.	29	10·8	En.	s.
9	6·9	Di.	n.	20	5·6	Di.	n.		16·8	Rh.	s.
	9·1	Rh.	n.		7·5	Te.	s.		17·3	Mi.	n.
	11·1	Mi.	s.		13·1	En.	n.		17·9	Te.	s.
	14·1	En.	n.		16·1	Rh.	s.		19·4	Di.	s.
	22·3	Te.	n.		18·5	Mi.	s.	30	15·9	Mi.	n.
10	15·8	Di.	s.	21	6·1	Te.	n.		16·6	Te.	n.
	21·0	Te.	s.		14·5	Di.	s.		19·7	En.	s.
	21·0	Mi.	n.		17·1	Mi.	s.	Dec. 1	4·3	Di.	n.
	23·0	En.	n.		22·0	En.	n.		12·2	En.	n.
11	15·3	Rh.	s.	22	4·8	Te.	s.		14·5	Mi.	n.
	15·4	En.	s.		14·4	En.	s.		15·2	Te.	s.
	19·6	Te.	n.		15·7	Mi.	s.		23·0	Rh.	n.
	19·6	Mi.	n.		22·3	Rh.	n.	2	13·1	Di.	s.
12	0·6	Di.	n.		23·3	Di.	n.		13·1	Mi.	n.
	7·9	En.	n.	23	3·4	Te.	n.		13·9	Te.	n.
	18·2	Mi.	n.		6·9	En.	n.		21·0	En.	n.
	18·3	Te.	s.		14·3	Mi.	s.	3	11·7	Mi.	n.
13	9·5	Di.	s.	24	2·1	Te.	s.		12·5	Te.	s.
	16·7	En.	n.		8·1	Di.	s.		13·5	En.	s.
	16·9	Mi.	n.		12·9	Mi.	s.		21·9	Di.	n.
	16·9	Te.	n.		15·8	En.	n.	4	5·1	Rh.	s.
	21·5	Rh.	n.	25	0·7	Te.	n.		5·9	En.	n.
14	15·6	Te.	s.		4·4	Rh.	s.		10·4	Mi.	n.
	18·3	Di.	n.		8·2	En.	s.		11·2	Te.	n.
15	14·2	Te.	n.		11·5	Mi.	s.	5	6·8	Di.	s.
16	3·1	Di.	s.		17·0	Di.	n.		9·8	Te.	s.
	3·7	Rh.	s.		23·4	Te.	s.		14·8	En.	n.
	12·9	Te.	s.	26	10·1	Mi.	s.		20·3	Mi.	s.
17	11·3	Mi.	n.		17·1	En.	s.	6	7·2	En.	s.
	11·5	Te.	n.		22·0	Te.	n.		8·5	Te.	n.

1886.	h		
Dec. 6	11·3	Rh.	n.
	15·6	Di.	n.
	18·9	Mi.	s.
7	7·1	Te.	s.
	16·1	En.	s.
	17·5	Mi.	s.
8	0·4	Di.	s.
	5·7	Te.	n.
	8·5	En.	n.
	16·1	Mi.	s.
	17·5	Rh.	s.
9	4·4	Te.	s.
	9·2	Di.	n.
	14·7	Mi.	s.
	17·4	En.	n.
10	3·0	Te.	n.
	9·8	En.	s.
	13·3	Mi.	s.
	18·1	Di.	s.
	23·6	Rh.	n.
11	1·7	Te.	s.
	12·0	Mi.	s.
	18·7	En.	s.
12	0·3	Te.	n.
	2·9	Di.	n.
	23·0	Te.	s.
13	5·8	Rh.	s.
	11·7	Di.	s.
	21·6	Te.	n.
14	12·5	En.	s.
	20·3	Te.	s.
	20·5	Di.	n.
15	11·9	Rh.	n.
	17·7	Mi.	n.
	18·9	Te.	n.
	21·3	En.	s.
16	5·4	Di.	s.
	13·8	En.	n.
	16·3	Mi.	n.
	17·6	Te.	s.

1886.	h		
Dec. 17	6·2	En.	s.
	14·2	Di.	n.
	14·9	Mi.	n.
	16·2	Te.	n.
	18·1	Rh.	s.
18	13·6	Mi.	n.
	14·8	Te.	s.
	15·1	En.	s.
	23·0	Di.	s.
19	7·5	En.	n.
	12·2	Mi.	n.
	13·5	Te.	n.
20	0·3	Rh.	n.
	7·8	Di.	n.
	10·8	Mi.	n.
	12·1	Te.	s.
	16·4	En.	n.
21	8·8	En.	s.
	9·4	Mi.	n.
	10·8	Te.	n.
	16·6	Di.	s.
22	6·4	Rh.	s.
	8·0	Mi.	n.
	9·4	Te.	s.
	17·7	En.	s.
	19·3	Mi.	s.
23	1·5	Di.	n.
	8·1	Te.	n.
	10·2	En.	n.
	17·9	Mi.	s.
24	6·7	Te.	s.
	10·3	Di.	s.
	12·6	Rh.	n.
	16·5	Mi.	s.
	19·0	En.	n.
25	5·4	Te.	n.
	11·5	En.	s.
	15·2	Mi.	s.
	19·1	Di.	n.
26	4·0	Te.	s.

1886.	h		
Dec. 26	13·8	Mi.	s.
	18·7	Rh.	s.
	20·3	En.	s.
27	2·6	Te.	n.
	3·9	Di.	s.
	12·4	Mi.	s.
	12·8	En.	n.
28	1·3	Te.	s.
	5·2	En.	s.
	11·0	Mi.	s.
	12·8	Di.	n.
	23·9	Te.	n.
29	0·9	Rh.	n.
	9·6	Mi.	s.
	14·1	En.	s.
	21·6	Di.	s.
	22·6	Te.	s.
30	6·5	En.	n.
	8·2	Mi.	s.
	21·2	Te.	n.
31	6·4	Di.	n.
	7·0	Rh.	s.
	15·4	En.	n.
	18·1	Mi.	n.
	19·9	To.	s.
1887.			
Jan. 1	7·8	En.	s.
	15·2	Di.	s.
	16·7	Mi.	n.
	18·5	Te.	n.
2	13·2	Rh.	n.
	15·4	Mi.	n.
	16·7	En.	s.
	17·1	Te.	s.
3	0·0	Di.	n.
	9·2	En.	n.
	14·0	Mi.	n.
	16·0	Te.	n.
4	8·9	Di.	s.
	12·6	Mi.	n.

1887.	h			1887.	h			1887.	h		
Jan.	4	14·4	Te.	s.	Jan.	16	2·0	Rh.	n.	Jan.	25	6·1	Mi.	n.
		18·0	En.	n.			7·3	Mi.	s.			7·2	En.	n.
		19·3	Rh.	s.			9·5	En.	s.			8·6	Te.	s.
	5	10·5	En.	s.			18·3	Di.	n.		26	7·2	Te.	n.
		11·2	Mi.	n.			20·8	Te.	n.			8·0	Di.	s.
		13·1	Te.	n.		17	17·2	Mi.	n.			16·0	Mi.	s.
		17·7	Di.	n.			18·3	En.	s.			16·0	En.	n.
	6	9·8	Mi.	n.			19·4	Te.	s.		27	5·9	Te.	s.
		11·7	Te.	s.		18	3·1	Di.	s.			8·5	En.	s.
		19·3	En.	s.			8·3	Rh.	s.			8·9	Rh.	s.
	7	1·5	Rh.	n.			10·8	En.	n.			14·6	Mi.	s.
		2·5	Di.	s.			15·8	Mi.	n.			14·8	Di.	n.
		8·4	Mi.	n.			18·1	Te.	n.		28	4·5	Te.	n.
		10·4	Te.	n.		19	11·9	Di.	n.			13·2	Mi.	s.
		11·8	En.	n.			14·4	Mi	n.			17·3	En.	s.
	8	9·0	Te.	s.			16·7	Te.	s.			23·7	Di.	s.
		11·3	Di.	n.			19·6	En.	n.		29	3·2	Te.	s.
	9	7·6	Rh.	s.		20	12·1	En.	s.			9·8	En.	n.
		7·6	Te.	n.			13·0	Mi.	n.			11·9	Mi.	s.
		20·2	Di.	s.			14·4	Rh.	n.			15·0	Rh.	n.
	10	6·3	Te.	s.			15·4	Te.	n.		30	1·8	Te.	n.
	11	4·9	Te.	n.			20·7	Di.	s.			8.5	Di.	n.
		5·0	Di.	n.		21	4·5	En.	n.			10·5	Mi.	s.
		13·8	Rh.	n.			11·6	Mi.	n.			18·7	En.	n.
	12	3·6	Te.	s.			14·0	Te.	s.		31	0·5	Te.	s.
		13·8	Di.	s.		22	5·6	Di.	n.			9·1	Mi.	s.
	13	2·2	Te.	n.			10·2	Mi.	n.			11·1	En.	s.
		11·3	Mi.	s.			12·7	Te.	n.			17·3	Di.	s.
		15·7	En.	s.			13·4	En.	n.			21·2	Rh.	s.
		19·9	Rh.	s.			20·6	Rh.	s.			23·1	Te.	n.
	14	0·6	Di.	n.		23	5·8	En.	s.	Feb.	1	3·5	En.	n.
		0·9	Te.	s.			8·9	Mi.	n.			7·7	Mi.	s.
		8·1	En.	n.			11·3	Te.	s.			21·8	Te.	s.
		9·9	Mi.	s.			14·4	Di.	s.		2	2·2	Di.	n.
		23·5	Te.	n.		24	7·5	Mi.	n.			6·3	Mi.	s.
	15	8·6	Mi.	s.			9·9	Te.	n.			12·4	En.	n.
		9·4	Di.	s.			14·7	En.	s.			17·6	Mi.	n.
		17·0	En.	n.			23·2	Di.	n.			20·4	Te.	n.
		22·2	Te.	s.		25	2·7	Rh.	n.		3	3·4	Rh.	n.

1887.	h		
Feb. 3	4·9	En.	s.
	4·9	Mi.	s.
	11·0	Di.	s.
	16·2	Mi.	n.
	19·0	Te.	s.
4	13·7	En.	s.
	14·8	Mi.	n.
	17·7	Te.	n.
	19·8	Di.	n.
5	9·5	Rh.	s.
	16·3	Te.	s.
6	4·6	Di.	s.
	15·0	Te.	n.
7	7·5	En.	s.
	10·7	Mi.	n.
	13·5	Di.	n.
	13·6	Te.	s.
	15·7	Rh.	n.
8	9·3	Mi.	n.
	12·3	Te.	n.
	16·4	En.	s.
	20·6	Mi.	s.
	22·3	Di.	s.
9	7·9	Mi.	n.
	8·8	En.	n.
	10·9	Te.	s.
	21·9	Rh.	s.
10	6·5	Mi.	n.
	7·1	Di.	n.
	9·6	Te.	n.
	17·7	En.	n.
	17·8	Mi.	s.
11	8·2	Te.	s.
	10·1	En.	s.
	15·9	Di.	s.
	16·5	Mi.	s.
12	4·0	Rh.	n.
	6·9	Te.	n.
	15·1	Mi.	s.

1887.	h		
Feb. 12	19·0	En.	s.
13	0·8	Di.	n.
	5·5	Te.	s.
	11·4	En.	n.
	13·7	Mi.	s.
14	3·9	En.	s.
	4·2	Te.	n.
	9·6	Di.	s.
	10·2	Rh.	s.
	12·3	Mi.	s.
15	2·8	Te.	s.
	10·9	Mi.	s.
	12·8	En.	s.
	18·4	Di.	n.
16	1·5	Te.	n.
	5·2	En.	n.
	9·5	Mi.	s.
	16·4	Rh.	n.
17	0·1	Te.	s.
	3·3	Di.	s.
	8·2	Mi.	s.
	14·1	En.	n.
	22·8	Te.	n.
18	6·5	En.	s.
	6·8	Mi.	s.
	12·1	Di.	n.
	18·1	Mi.	n.
	21·4	Te.	s.
	22·6	Rh.	s.
19	15·4	En.	s.
	16·7	Mi.	n.
	20·1	Te.	n.
	20·9	Di.	s.
20	7·8	En.	n.
	15·3	Mi.	n.
	18·7	Te.	s.
21	4·7	Rh.	n.
	5 8	Di.	n.
	13·9	Mi.	n.

1887.	h		
Feb. 21	16·7	En.	n.
	17·4	Te.	n.
22	9·2	En.	s.
	12·6	Mi.	n.
	14·6	Di.	s.
	16·0	Te.	s.
23	10·9	Rh.	s.
	11·2	Mi.	n.
	14·7	Te.	n.
	18·1	En.	s.
	23·4	Di.	n.
24	9·8	Mi.	n.
	10·5	En.	n.
	13·3	Te.	s.
25	2·9	En.	s.
	8·3	Di.	s.
	8·4	Mi.	n.
	12·0	Te.	n.
	17·1	Rh.	n.
26	7·0	Mi.	n.
	10·6	Te.	s.
	11·8	En.	s.
	17·1	Di.	n.
27	4·3	En.	n.
	5·6	Mi.	n.
	9·3	Te.	n.
	17·0	Mi.	s.
	23·3	Rh.	s.
28	1·9	Di.	s.
	7·9	Te.	s.
	13·1	En.	n.
	15·6	Mi.	s.
March 1	5·6	En.	s.
	6·6	Te.	n.
	10·8	Di.	n.
	14·2	Mi.	s.
2	5·2	Te.	s.
	5·5	Rh.	n.
	12 8	Mi.	s.

1887.	h			1887.	h			1887.	h		
March 2	14·5	En.	s.	March 13	12·5	Rh.	s.	March 22	7·8	Mi.	s.
	19·6	Di.	s.		13·1	Te.	s.		11·3	En.	n.
3	3·9	Te.	n.		13·6	En.	s.		13·4	Rh.	s.
	6·9	En.	n.		18·3	Di.	s.		23 6	Te.	s.
	11·4	Mi.	s.	14	6·0	En.	n.	23	3·8	En.	s.
4	2·5	Te.	s.		7·5	Mi.	n.		6·4	Mi.	s.
	4·5	Di.	n.		11·7	Te.	n.		8·3	Di.	n.
	11·7	Rh.	s.	15	3·2	Di.	n.		22·3	Te.	n.
5	1·2	Te.	n.		6·2	Mi.	n.	24	12·7	En.	s.
	13·3	Di.	s.		10·4	Te.	s.		16·4	Mi.	n.
	23·8	Te.	s.		14·9	En.	n.		17·1	Di.	s.
6	17·9	Rh.	n.		18·7	Rh.	n.		19·6	Rh.	n.
	22·1	Di.	n.	16	4·8	Mi.	n.		20·9	Te.	s.
	22·5	Te.	n.		7·3	En.	s.	25	5·1	En.	n.
7	9·6	En.	n.		9·0	Te.	n.		15·0	Mi.	n.
	17·2	Mi.	n.		12·0	Di.	s.		19·6	Te.	n.
	21·1	Te.	s.		16·1	Mi.	s.	26	2·0	Di.	n.
8	7·0	Di.	s.	17	7·7	Te.	s.		13·6	Mi.	n.
	15·8	Mi.	n.		14·7	Mi.	s.		14·0	En.	n.
	18·5	En.	n.		16·2	En.	s.		18·2	Te.	s.
	19·8	Te.	n.		20 9	Di.	n.	27	1·8	Rh.	s.
9	0·1	Rh.	s.	18	0·9	Rh.	s.		6·4	En.	s.
	10·9	En.	s.		6·3	Te.	n.		10·8	Di.	s.
	14·4	Mi.	n.		8·7	En.	n.		12·2	Mi.	n.
	15·8	Di.	n.		13·3	Mi.	s.		16·9	Te.	n.
	18·4	Te.	s.	19	5·0	Te.	s.	28	10·9	Mi.	n.
10	3·3	En.	n.		5·7	Di.	s.		15·3	En.	s.
	13·1	Mi.	n.		12·0	Mi.	s.		15·6	Te.	s.
	17·1	Te.	n.		17·6	En.	n.		19·7	Di.	n.
11	0·7	Di.	s.	20	3·6	Te.	n.	29	7·8	En.	n.
	6·3	Rh.	n.		7·2	Rh.	n.		8·1	Rh.	n.
	11·7	Mi.	n.		10·0	En.	s.		9·5	Mi.	n.
	12·2	En.	n.		10·6	Mi.	s.		14·2	Te.	n.
	15·7	Te.	s.		14·6	Di.	n.	30	0·2	En.	s.
12	4·7	En.	s.	21	2·3	Te.	s.		4·5	Di.	s.
	9·5	Di.	n.		2·4	En.	n.		8·1	Mi.	n.
	10·3	Mi.	n.		9·2	Mi.	s.		12·9	Te.	s.
	14·4	Te.	n.		23·4	Di.	s.	31	6·7	Mi.	n.
13	8·9	Mi.	n.	22	1·0	Te.	n.		9·1	En.	s.

1887.	h			1887.	h			1887.	h		
March 31	11·5	Te.	n.	April 10	4·3	Mi.	s.	April 20	6·1	En.	n.
	13·4	Di.	n.		15·8	En.	n.		7·4	Te.	s.
	14·3	Rh.	s.		20·8	Te.	s.		13·1	Mi.	s.
April 1	10·2	Te.	s.	11	8·3	En.	s.		22·5	Rh.	n.
	22·2	Di.	s.		12·2	Di.	n.	21	2·3	Di.	s.
2	8·9	Te.	n.		14·2	Mi.	n.		6·1	Te.	n.
	10·5	En.	n.		19·5	Te.	n.		11·7	Mi.	s.
	20·5	Rh.	n.		21·5	Rh.	n.		15·0	En.	n.
3	2·9	En.	s.	12	12·8	Mi.	n.	22	4·8	Te.	s.
	7·1	Di.	n.		17·2	En.	s.		7·4	En.	s.
	7·5	Te.	s.		18·1	Te.	s.		10·4	Mi.	s.
	13·9	Mi.	s.		21·1	Di.	s.		11·1	Di.	n.
4	6·2	Te.	n.	13	9·6	En.	n.	23	3·4	Te.	n.
	11·8	En.	s.		11·4	Mi.	n.		4·8	Rh.	s.
	12·5	Mi.	s.		16·8	Te.	n.		20·0	Di.	s.
	16·0	Di.	s.	14	2·1	En.	s.	24	2·1	Te.	s.
5	2·9	Rh.	s.		3·8	Rh.	s.	25	0·7	Te.	n.
	4·2	En.	n.		6·0	Di.	n.		4·8	Di.	n.
	4·8	Te.	s.		10·1	Mi.	n.		11·0	Rh.	n.
	11·1	Mi.	s.		15·5	Te.	s.		23·4	Te.	s.
6	0·8	Di.	n.	15	8·7	Mi.	n.	26	13·7	Di.	s.
	3·5	Te.	n.		10·9	En.	s.		22·1	Te.	n.
	9·8	Mi.	s.		14·1	Te.	n.	27	17·3	Rh.	s.
	13·1	En.	n.		14·8	Di.	s.		20·7	Te.	s.
7	2·2	Te.	s.	16	3·4	En.	n.		22·6	Di.	n.
	5·6	En.	s.		7·3	Mi.	n.	28	19·4	Te.	n.
	8·4	Mi.	s.		10·0	Rh.	n.	29	7·4	Di.	s.
	9·0	Rh.	n.		12·8	Te.	s.		18·1	Te.	s.
	9·7	Di.	s.		23·7	Di.	n.		23·4	Rh.	n.
8	0·8	Te.	n.	17	11·4	Te.	n.	30	16·3	Di.	n.
	7·0	Mi.	s.		12·3	En.	n.		16·7	Te.	n.
	14·5	En.	s.	18	4·7	En.	s.	May 1	15·4	Te.	s.
	18·5	Di.	n.		8·5	Di.	s.	2	1·2	Di.	s.
	23·5	Te.	s.		10·1	Te.	s.		5·8	Rh.	s.
9	5·6	Mi.	n.		16·3	Rh.	s.		14·1	Te.	n.
	6·9	En.	s.	19	8·8	Te.	n.	3	10·0	Di.	n.
	15·2	Rh.	s.		13·6	En.	s.		12·7	Te.	s.
	22·1	Te	n.		14·5	Mi.	s.	4	11·4	Te.	n.
10	3·4	Di.	s.		17·4	Di.	n.		12·1	Rh.	n.

1887.	h			1887.	h			1887.	h		
May 4	18·9	Di.	s.	May 7	7·4	Te.	s.	May 9	0·7	Rh.	n.
5	10·1	Te.	s.		12·4	Di.	s.		4·7	Te.	s.
6	3·8	Di.	n.	8	6·1	Te.	n.	10	3·4	Te.	n.
	8·7	Te.	n.		21·5	Di.	n.		6·4	Di.	s.
	18·4	Rh.	s.								

By means of this list of conjunctions, approximate values of the coördinates x and y, expressed in semi-diameters of the planet's equator, may be easily found for any other time t in the following little table, the argument of which is the interval τ between the time t and the time of the next preceding or following conjunction. The satellites are on the same side, north or south, of the major axis of the ring as at the time of the next conjunction, and, as they move in the direction of *de*creasing position-angles, they are in the interval between a "n" and a "s" conjunction on the preceding side, and between a "s" and a "n" conjunction on the following side of the direction of the minor axis of the ring. They are at their greatest elongations *Mi.* $5^h{\cdot}7$, *En.* $8^h{\cdot}2$, *Te.* $11^h{\cdot}3$, *Di.* $16^h{\cdot}4$, *Rh.* $27^h{\cdot}1$, before or after the times of conjunction.

τ	*Mimas.*		*Enceladus.*		*Tethys.*		*Dione.*		*Rhea.*	
h	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4	x_5	y_5
0	0·0	1·3	0·0	1·6	0·0	2·0	0·0	2·6	0·0	3·6
1	0·9	1·2	0·8	1·6	0·7	2·0	0·6	2·5	0·5	3·6
2	1·7	1·1	1·5	1·5	1·4	1·9	1·2	2·5	1·0	3·6
3	2·3	0·8	2·2	1·4	2·0	1·8	1·8	2·5	1·5	3·5
4	2·8	0·6	2·8	1·2	2·6	1·7	2·4	2·4	2·0	3·5
5	3·1	0·2	3·3	0·9	3·2	1·5	2·9	2·3	2·5	3·4
6	3·1	0·1	3·7	0·7	3·7	1·3	3·5	2·1	3·0	3·4
7	2·9	0·5	3·9	0·4	4·1	1·1	4·0	2·0	3·5	3·3
8	2·5	0·8	4·0	0·1	4·5	0·9	4·4	1·8	4·0	3·2
9	1·8	1·0	4·0	0·2	4·7	0·7	4·8	1·7	4·5	3·1
10	1·1	1·2	3·8	0·5	4·9	0·4	5·2	1·5	4·9	3·0
11					5·0	0·1	5·6	1·3	5·3	2·9
12							5·8	1·1	5·7	2·7
13							6·1	0·8	6·1	2·6
14							6·2	0·6	6·5	2·5
15							6·3	0·3	6·8	2·3
16							6·4	0·1	7·1	2·1
20									8·2	1·4
27·1									8·9	0·0

Observers who are desirous to follow the motions of the satellites will do well to lay down the data of the table graphically

on a sufficiently large scale, so that, by marking the corresponding times for the night of observing, they may get information about the places of the satellites at a glance.

Differences of Right Ascension and Declination between the three outer Satellites and the Centre of Saturn.

Greenwich Noon. 1886.	*Titan.*		*Hyperion.*		*Iapetus.*	
	$\alpha_6-A.$	$\delta_6-D.$	$\alpha_7-A.$	$\delta_7-D.$	$\alpha_8-A.$	$\delta_8-D.$
	s	"	s	"	s	"
Sept. 30	− 7·36	−71·0	−13·61	+ 6·5	−26·71	−103·8
Oct. 1	− 2·82	−74·8	−14·96	− 21·3	24·63	104·9
2	+ 2·13	−68·2	−14·80	− 47·0	−22·40	−105·4
3	+ 6·80	−51·9	−13·28	− 68·5	20·02	105·2
4	+10·49	−28·0	−10·68	− 84·4	−17·50	−104·4
5	+12·64	+ 0·0	− 7·26	− 94·1	14·86	102·9
6	+12·83	+28·2	− 3·33	− 97·3	−12·13	−100·8
7	+11·00	+51·9	+ 0·84	− 94·2	9·31	98·1
8	+ 7·35	+67·1	+ 4·96	− 85·2	− 6·42	− 94·8
9	+ 2·48	+71·3	+ 8·80	− 70·9	3·48	91·0
10	− 2·83	+63·5	+12·10	− 52·1	− 0·51	− 86·6
11	− 7·70	+45·3	+14·64	− 29·9	+ 2·48	81·7
12	−11·34	+19·7	+16·21	− 5·8	+ 5·46	− 76·3
13	−13·23	− 9·1	+16·61	+ 18·9	8·42	70·5
14	−13·14	−36·6	+15·70	+ 42·2	+11·34	− 64·2
15	−11·12	−58·8	+13·42	+ 61·8	14·21	57·6
16	− 7·50	−72·7	+ 9·84	+ 75·4	+17·01	− 50·6
17	− 2·81	−76·4	+ 5·19	+ 81·0	19·73	43·3
18	+ 2·30	−69·4	− 0·08	+ 77·1	+22·34	− 35·8
19	+ 7·09	−52·3	− 5·35	+ 63·6	24·83	28·0
20	+10·87	−27·8	− 9·98	+ 43·1	+27·19	− 20·0
21	+13·03	+ 1·9	−13·41	+ 15·4	29·40	11·9
22	+13·19	+29·8	−15·32	− 13·3	+31·46	− 3·8
23	+11·23	+53·8	−15·65	− 40·6	33·34	− 4·4
24	+ 7·43	+69·1	−14·51	− 64·5	+35·04	+ 12·6
25	+ 2·37	+73·0	−12·16	− 82·7	36·54	20·8
26	− 3·10	+64·6	− 8·86	− 94·9	+37·84	+ 28·9
27	− 8·08	+45·5	− 4·92	−100·4	38·93	36·8
28	−11·78	+19·1	− 0·63	− 99·3	+39·80	+ 44·6
29	−13·66	−10·5	+ 3·71	− 91·9	40·44	52·1
30	−13·49	−38·6	+ 7·84	− 78·7	+40·85	+ 59·3
31	−11·33	−61·2	+11·49	− 60·6	41·02	66·3

Greenwich Noon. 1886.		*Titan.* $\alpha_4-A.$	*Titan.* $\delta_4-D.$	*Hyperion.* $\alpha_7-A.$	*Hyperion.* $\delta_7-D.$	*Iapetus.* $\alpha_8-A.$	*Iapetus.* $\delta_8-D.$
		s	"	s	"	s	"
Nov.	1	− 7·54	−75·1	+14·43	− 38·6	+40·96	+ 72·9
	2	− 2·67	−78·4	+16·41	− 13·9	40·65	79·1
	3	+ 2·59	−70·7	+17·23	+ 11·8	+40·10	+ 84·8
	4	+ 7·50	−52·9	+16·71	+ 36·7	39·31	90·1
	5	+11·33	−27·2	+14·76	+ 58·5	+38·29	+ 94·9
	6	+13·47	+ 2·6	+11·40	+ 74·8	37·04	99·1
	7	+13·52	+32·0	+ 6·83	+ 83·2	+35·55	+102·7
	8	+11·40	+56·5	+ 1·46	+ 82·0	33·85	105·8
	9	+ 7·40	+71·7	− 4·11	+ 70·7	+31·93	+108·3
	10	+ 2·14	+75·0	− 9·18	+ 50·5	29·80	110·1
	11	− 3·49	+65·7	−13·13	+ 23·9	+27·49	+111·2
	12	− 8·57	+45·5	−15·58	− 5·7	24·99	111·6
	13	−12·29	+17·9	−16·37	− 34·8	+22·32	+111·4
	14	−14·11	−12·6	−15·59	− 60·7	19·51	110·4
	15	−13·79	−41·4	−13·46	− 81·5	+16·56	+108·8
	16	−11·45	−64·2	−10·26	− 96·0	13·49	106·4
	17	− 7·46	−78·0	− 6·31	−103·7	+10·32	+103·4
	18	− 2·40	−80·7	− 1·92	−104·5	7·08	99·6
	19	+ 3·02	−72·0	+ 2·61	− 98·5	+ 3·77	+ 95·2
	20	+ 8·02	−53·0	+ 6·99	− 86·4	+ 0·43	+ 90·2

The rest will be published in the Supplementary Number of the *Monthly Notices*.

In order that the errors of the predicted positions of *Hyperion* may be kept within sufficiently narrow limits, it is essential that the latest observed positions should be available. Observers will oblige by timely publication or communication of the positions resulting from their measurements.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLVI. SUPPLEMENTARY NUMBER. No. 9

Observations of the Variable Star R Carinæ from Sept. 1883, *to April* 1886. By John Tebbutt.

In the *Monthly Notices*, vol. xliv. p. 14, was published a series of concluded magnitudes of this variable, from comparisons extending from May 11, 1880, to September 3, 1883. I have now much pleasure in presenting to the Society another series, based on comparisons extending from the latter date to the close of April 1886. While the variable was visible to the unassisted eye, it was compared with neighbouring stars of the *Uranometria Argentina*, and while telescopic, with the small stars, whose positions and magnitudes are recorded on p. 17 of the *Monthly Notices* already referred to. The variable could not be seen with the unassisted eye on April 22, 1884, but was pretty distinct on the 15th of the following month. On March 12, 13, December 26, 1885, it was visible without a telescope, on the last-mentioned date distinctly so, but on April 3, 1886, it was remarked as barely visible without telescopic aid, although the sky was beautifully clear and the Moon absent. The $3\frac{1}{4}$-inch Refractor was employed in almost all the comparisons when the star was telescopic. I have not yet thoroughly discussed the Cordoba and Windsor observations; but it appears, from a cursory examination, that a period of about 312 days will approximately represent the maxima of the star. In conclusion, I shall be obliged by the following corrections of errata in my former paper :—

1882, April 9, *for* 9·2 *read* 9·3

„ „ 15, „ 9·3 „ 9·2

Concluded Magnitudes of R Carinæ.

Date.	Mag.	Date.	Mag.	Date.	Mag.
1883, Sept. 30	8·5	1885, Jan. 4	9·1	1885, Sept. 6	9·2
,, Nov. 12	9·1	,, ,, 12	9·0	,, Nov. 11	8·1
,, ,, 19	9·2	,, ,, 16	8·9	,, Dec. 16	6·8
,, Dec. 7	9·2	,, ,, 30	8·6	,, ,, 26	6·0
,, ,, 18	9·1	,, Feb. 4	8·5	1886, Jan. 8	4·9
,, ,, 25	9·1	,, ,, 8	8·5	,, ,, 12	5·1
1884, Jan. 3	9·1	,, ,, 26	7·0	,, ,, 26	4·6
,, ,, 22	9·0	,, Mar. 15	6·4	,, ,, 30	4·6
,, Mar. 18	8·5	,, Apr. 2	5·8	,, Feb. 4	4·7
,, ,, 31	8·2	,, ,, 11	5·7	,, ,, 9	4·9
,, Apr. 14	7·2	,, ,, 22	6·0	,, ,, 11	5·1
,, ,, 22	6·8	,, ,, 23	6·0	,, ,, 21	5·3
,, May 15	6·1	,, May 1	6·3	,, ,, 25	5·3
,, ,, 30	5·7	,, ,, 3	6·4	,, Mar. 4	5·3
,, June 17	6·4	,, ,, 16	6·4	,, ,, 7	5·3
,, ,, 26	6·5	,, June 3	7·3	,, ,, 8	5·3
,, July 7	6·9	,, July 1	8·4	,, ,, 14	5·6
,, ,, 22	7·7	,, ,, 25	8·7	,, ,, 27	5·9
,, Dec. 12	9·2	,, Aug. 18	9·1	,, Apr. 1	6·3
,, ,, 18	9·3	,, ,, 31	9·2	,, ,, 21	7·3

Windsor, N. S. Wales:
1886, May 1.

Observation of Calliope, made at the Observatory, Düsseldorf.
By R. Luther.

(*Extract from a letter to Mr. Stone.*)

Mr. Hind's planet (22) *Calliope* has not been observed since 1874 (three times at Paris). I have made the following new observations of it:—

Mean time, Düsseldorf.	(22) *Calliope* (9·6 mag.)		
	h m s	h m s	° ′ ″
1886, Sept. 18,	10 52 0	R.A. 23 58 16·49.	Decl. −22 40 41·8 } 6 comp. with Arg. Z. 269, N. 42
	parallactical correction	−0·07	+ 4·6 }

This observation may perhaps be useful to English observers.

Düsseldorf: 1886, *September* 21.

Observations of Comets, 1877 I., II., III., VI., 1880 III., 1882 III., and 1884 III., made at Dun Echt Observatory, with the 15-in. Refracting Telescope.

(*Communicated by the Earl of Crawford and Balcarres.*)

Comet 1877 I.

Date. 1877.	Dun Echt Mean Time.	Δα (Ø−✱)	Δδ	α (Ø)	δ (Ø)	Star.	Observer.
	h m s	m s	′ ″	h m s	° ′ ″		
Feb. 21	15 12 13·8	+0 52·30	+8 46·7	20 40 50·03	+74 58 2·3	*a*	R. C.
21	15 48 5·5	+0 13·00	−2 2·1	20 42 39·55	+75 3 17·5	*b*	R. C.
25	12 54 38·9	+1 41·36	−8 58·3	1 52 25·69	+74 45 36·6	*c*	R. C.
28	7 56 9·1	+0 2·03	−4 7·8	3 6 9·55	+68 31 13·4	*d*	R. C.
Mar. 4	9 49 55·1	−0 11·17	+2 48·1	3 45 3·56	+61 35 15·3	*e*	R. C. 6 meas.
4	10 27 44·9	−0 3·54	+0 42·8	3 45 11·19	+61 33 10·0	*e*	R. C. 2 meas.
18	10 11 2·8	+0 30·15	+1 19·0	4 23 26·25	+50 31 29·2	*f*	R. C.
19	11 59 48·3	+0 2·98	+1 43·2	4 25 0·29	+50 3 58·7	*g*	R. C.

Comet 1877 II.

April 18	15 40 40	+0 2·58	+2 20·5	22 22 5·79	+33 24 34·6	*h*	J. G. L. and R. C.
19	15 3 49	−0 26·53	+2 20·9	22 23 45·34	+35 8 1·8	*i*	R. C. 5 meas.
19	15 47 47	−0 23·32	+5 38·3	22 23 48·55	+35 11 19·2	*i*	J. G. L. 3 meas.
25	12 56 32	−0 14·09	+6 39·2	22 37 31·37	+46 37 57·6	*k*	J. G. L.
25	13 19 55	−0 10·96	+8 42·6	22 37 34·50	+46 40 1·0	*k*	R. C.
26	11 57 3	+1 7·23	−0 22·8	22 40 35·38	+48 38 47·2	*l*	R. C.

Date. 1877.	Dun Echt Mean Time. h m s	$\alpha' - \alpha$	$\Delta\delta$	α'	δ'	Star.	Observer.
				Comet 1877 *III.*			
		m s	′ ″	h m s	° ′ ″		
April 18	12 2 24	−0 4·53	+5 30·5	1 42 28·36	+57 56 56·3	*m*	R. C.
18	12 39 54	+0 11·16	+6 16·9	1 42 44·05	+57 57 42·7	*m*	J. G. L.
19	13 36 59	+0 27·47	−4 17·7	1 53 8·53	+58 36 14·4	*n*	R. C.
19	13 57 20	+0 36·71	−3 43·0	1 53 17·77	+58 36 49·2	*n*	J. G. L.
29	12 24 48	+0 45·98	+4 20·2	3 55 57·09	+61 31 46·9	*o*	J. G. L.
				Comet 1877 *VI.*			
Nov. 13	14 26 4	+0 5·87	−0 19·4	6 0 39·84	+15 36 38·3	*p*	R. C. and J. G. L.
27	11 52 43	−0 2·43	−3 38·7	4 52 20·64	− 0 6 53·4	*q*	R. C.
				Comet 1880 *III.*			
1880. Oct. 6	8 18 56	−3 7·57	... ...	16 6 58·48	... ...	*r*	R. C.
6	8 41 14	... ...	−9 58·5	... ...	+24 39 51·0	*r*	R. C.
19	7 47 18	−1 15·85	... ...	17 40 29·93	... ...	*s*	J. G. L.
19	7 47 50	... ...	+0 27·0	... ...	+15 5 36·8	*s*	J. G. L.
19	7 47 56	−1 43·43	... ...	17 40 30·17	... ...	*t*	J. G. L.
19	7 49 13	... ...	+0 38·2	... ...	+15 5 30·8	*t*	J. G. L.
25	7 19 5	+0 31·58	+7 26·2	18 1 26·18	+12 27 45·7	*u*	J. G. L.
				Comet 1882 *III.* (*Barnard*).			
1882. Sept. 16	15 32 30	+0 18·32	+0 16·5	7 22 54·07	+14 36 4·5	*v*	J. G. L.
17	14 44 34	+2 4·58	+1 39·0	7 24 49·50	+13 47 54·5	*w*	J. G. L.

Comet 1884 *III.*

Date. 1884.	Dun Echt Mean Time. h m s	✱−✱ Δα m s	Δδ ′ ″	α✱ h m s	δ✱ ° ′ ″	Star.	Observer.
Sept. 22	14 5 46	+0 12·51	−1 40·9	21 16 21·29	+21 26 18·6	*x*	R. C.
22	15 13 54	+1 21·75	−7 40·3	21 16 22·77	+21 25 0·1	*y*	R. C.
24	12 28 27	−1 10·08	+4 18·0	21 17 25·73	+20 33 58·5	*z*	R. C.
27	11 26 38	+2 37·13	−7 30·0	21 19 23·75	+19 11 31·4	*a*	R. C.

Observers, Ralph Copeland and J. G. Lohse.

Adopted Mean Places of Comparison Stars.

Star.	α, 1877·0. h m s	Red. s	δ, 1877·0. ° ′ ″	Red. ″	Authority.
a	20 40 3·87	−6·14	+74 49 27·6	−12·0	2 Dun Echt Merid. Obs.
b	20 42 32·84	−6·29	+75 5 31·3	−11·7	1 „ „
c	1 50 47·79	−3·46	+74 54 13·2	+21·7	Mean of A.-Ö. 2180, 5 Rad. and Bonn Obs., Vol. VI.
d	3 6 8·30	−0·78	+68 34 57·1	+24·1	Bonn Obs., Vol. VI.
e	3 45 14·59	+0·14	+61 32 4 2	+23·0	4 Dun Echt Merid. Obs.
f	4 22 55·66	+0·44	+50 29 50·9	+19·2	3 „ „
g	4 24 56·87	+0·44	+50 1 56·5	+19·0	2 „ „
h	22 22 4·09		+33 22 30·4		Lalande 43881, not used.
h	22 22 3·34	−0·13	+33 22 25·1	−11·0	2 resp. 3 Dun Echt Obs.
i	22 24 12·03	−0·16	+35 5 52·0	−11·1	Bessel-Weisse, 22ʰ, 512.
k	22 37 46·16		+46 31 28·1		A.-Ö. 24559, '60, not used.
k	22 37 45·92	−0·46	+46 31 30·1	−11·7	5 Dun Echt Obs. '77–'79.
l	22 39 28·69	−0·54	+48 39 21·9	−11·9	5 „ „

Star.	α, 1877·0. h m s	Red. s	δ, 1877·0. ° ′ ″	Red. ″	Authority.
m	1 42 34·89		+57 51 19·0		A.-Ö. 2031, not used.
m	1 42 34·52	−1·63	+57 51 20·1	+ 5·7	Helsingfors Zones 258 and 261.
n	1 52 42·70	−1·64	+58 40 25·6	+ 6·5	2 Dun Echt Obs.
o	3 55 12·09		+61 27 9·5		A.-Ö. 4396, not used.
o	3 55 12·03	−0·92	+61 27 13·0	+13·7	Helsingfors Zones 299, 547 and 588.
p	6 0 29·32	+4·65	+15 36 48·4	+ 9·3	Bessel–W$_2$, V, 1976.*
q	4 52 18·43	+4·64	− 0 3 31·3	+16·6	Gött. Cat. 1401–2.
	α 1880·0.		δ 1880·0.		
r	16 10 4·21	+1·84	+24 49 47·4	+ 2·1	B.-W$_2$, XVI. 274.
s	17 41 43·46	+2·32	+15 5 0·9	+ 8·9	B.-W$_2$, XVII. 1309.
t	17 42 11·28	+2·32	+15 4 43·7	+ 8·9	B.-W$_2$, XVII. 1327.
u	18 0 52·19	+2·41	+12 20 9·7	+ 9·8	B.-W$_2$, XVII. 1266.
	α 1882·0		δ 1882·0		
v	7 22 32·99	+2·76	+14 35 56·0	− 8·0	2 Leipzig Merid. Obs. A. N. 2457.
w	7 22 42·15	+2·77	+13 46 23·3	− 7·8	B.-W. VII. 636.
	α 1884·0.		δ 1884·0.		
x	21 16 5·38	+3·40	+21 27 29·5	+30·0	2 Dun Echt Obs. 1886.
y	21 14 57·63	+3·39	+21 32 10·4	+30·0	B.-W$_2$, XXI. 319.
z	21 18 32·42	+3·39	+20 29 10·4	+30·1	Bonn Obs. VI., +20°, 4902.
a	21 16 43·28	+3·34	+19 18 31·2	+30·2	1 Pegasi, Berl. J. B.

The star *e* = D.M. +61°, 648, is decidedly red in colour; 1877, March 4.
The star *o* = D.M. +61°, 667, is of a very deep orange colour; 1877, April 29.

* The star D.M. +15°, 1076, 9^m·5 does not exist as a single star, although there are several small stars about the place given in the D.M.

Remarks and Descriptions.

COMET 1877 I.

The observations on February 21 were made with a ring micrometer; all the others are derived from measures of position and distance with the filar micrometer. Refraction has been fully taken into account.

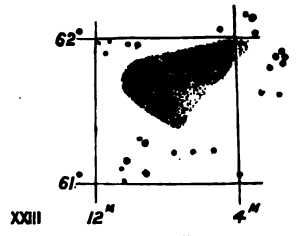
March 4.—The second observation was made to test the effect of the approach to a star on the measures. But eventually, as the central distance became very small, it was impossible to distinguish the relative position of the star and the densest part of the comet. About $10^h\ 39^m{\cdot}0$ ($9^h\ 30^m$ by chronometer) the comet seemed to pass centrally over the star. As usual in similar cases, this estimate differs considerably from the measures, which indicate a central distance of $10''{\cdot}6$ at that time.

March 19.—Comet very faint; round; $8''{\cdot}5$ in diameter.

COMET 1877 II.

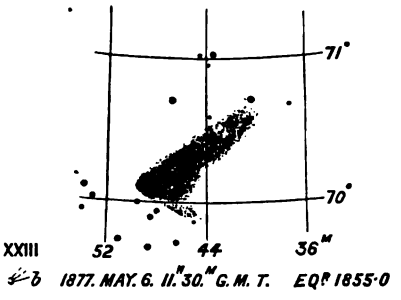
April 11.—The comet has a narrow tail about 18′ long. The nucleus about as bright as a 6½ mag. star.

April 13.—Tail about 31′ long, in position 260°.



May 2.—Sketched at $12^h\ 30^m$, G.M.T. The chief tail was 1½ field, or 56′ in length. The lateral tail was in position angle about 75° less than the main tail, but the interval was almost completely filled in with nebulosity. The outer edge of the chief tail is very well defined. Examined with power 430 the nucleus is fairly defined as a very small nebula in the midst of the coma, very suddenly exceedingly much brighter in the middle. Aurora and twilight very bright, or doubtless the tail could have been traced farther.

May 6.—Comet sketched at $11^h\ 30^m$, G.M.T.



For spectroscopic observations of comets 1877 II. and III., see *Monthly Notices*, vol. xxxvii. p. 430.

COMET 1877 III.

April 18.—Comet round; much brighter in the middle; $1\frac{1}{2}'$ in diameter.

April 29.—Comet round; gradually brighter in the middle; $57''$ in diameter.

COMET 1880 III.

1880, October 25.—Tail well visible, as broad as the coma; $15'$ long in position $62°{\cdot}6$, by two measures. There is no real nucleus, but the central part appears granulated.

COMET 1882 III. (*Barnard*).

1882, Sept. 16. The comet is fairly bright, gradually much brighter in the middle and about $2'$ in diameter with power 229.

COMET 1884 III.

1884, September 22.—This comet was found at Dun Echt by its spectrum, at $0^h\ 3^m$, sidereal time, with the object-glass prism, on the 6-inch Simms Equatorial. The next morning a telegram was received announcing that it had already been discovered by Herr Wolf, at Heidelberg, on September 17. (See *Ast. Nach.*, Bd. 110, col. 9.) In Dun Echt circular 91, the *time* is wrong.

September 24.—Comet about $3'$ diam.; elongated towards the $n\ p$ side; nucleus not in the middle.

September 27.—With power 229; diameter in parallel 6^s to 7^s; greatest condensation $n\ p$ the centre.

Observations of Comets d 1885 (*Fabry*); *e* 1885 (*Barnard*); *c* 1886 *and Brooks I.* 1886, *made at Sydney Observatory with the* 11½*-inch Refractor and Filar Micrometer.*

(*Communicated by H. C. Russell, B.A., Government Astronomer.*)

Observations of Comet d, 1885 (*Fabry*).

Date. 1886.	Sydney M.T. h m s	Star's Name.	Comparison Star's R.A. h m s	Comparison Star's N.P.D. ° ′ ″	Comet's diff. from Star. R.A. m s	Comet's diff. from Star. N.P.D. ′ ″	Comet's Apparent R.A. h m s	Comet's Apparent N.P.D. ° ′ ″	No. of Comp.	Observer.
May 2	6 48 59	151 Washington 1875	4 22 38·02	88 52 35·3	+0 48·65	0 0·0	4 23 26·67	88 52 35·3	11	H.C.R.
6	8 4 29	Lalande 11334	5 52 32·38	108 4 11·7	−1 29·69	+ 3 40·8	5 51 2·69	108 7 52·5	8	H.C.R.
10	9 7 26	3272 Cape Cat. 1880	6 49 1·25	118 23 28·0	−0 22·20	− 5 36·1	6 48 39·05	118 17 52·0	5	H.C.R.
12	7 48 15	3494	7 9 23·63	120 53 41·8	−1 13·45	+ 6 13·7	7 8 10·18	120 59 55·5	4	H.C.R.
13	7 27 8		7 16 34·34	122 5 22·8	0 0·00	0 0·0	7 16 34·34	122 5 22·8		J.A.P.
14	7 50 44	3715	7 29 6·89	123 9 37·4	−4 43·18	− 2 24·8	7 24 23·71	123 7 12·6	8	H.C.R.
19	7 49 28	3970	7 48 51·78	126 4 29·4	+4 44·75	+ 8 9·9	7 53 36·53	126 12 39·4	10	H.C.R.
20	8 50 6	4076	7 57 54·59	126 44 22·1	+0 12·73	− 5 56·9	7 58 7·32	126 38 25·2	10	H.C.R.
21	7 58 36	4071	7 57 27·11	126 58 26·8	+4 52·58	+ 3 17·1	8 2 19·69	127 1 43·9	10	H.C.R.
22	7 17 40	4147	8 4 26·96	127 21 18·8	+1 40·52	+ 0 47·2	8 6 7·48	127 22 5·9	10	H.C.R.
23	7 59 16	4207	8 8 40·64	127 35 17·1	+1 12·82	+ 6 29·5	8 9 53·46	127 41 46·6	10	J.A.P.
26	9 19 13	4458	8 29 24·62	128 27 57·1	−9 38·90	+ 2 55·9	8 19 45·72	128 30 53·0	3	H.C.R.
26	9 19 13	4354	8 22 6·67	128 41 31·9	−2 20·25	−10 39·9	8 19 46·42	128 30 52·0	3	H.C.R.
30	8 28 28	4482	8 31 0·81	129 35 7·4	−0 29·86	−14 13·8	8 30 30·95	129 20 53·6	10	H.C.R.
30	8 28 28	4482	8 31 0·81	129 35 7·4	−0 30·00	−14 12·5	8 30 30·81	129 20 54·9	7	J.A.P.
31	7 54 46	4482	8 31 0·80	129 35 7·2	+1 52·75	− 3 23·2	8 32 53·55	129 31 44·0	8	H.C.R.
31	7 54 46	4482	8 31 0·80	129 35 7·2	+1 52·27	− 3 21·7	8 32 53·07	129 31 45·5	6	J.A.P.
June 1	8 20 46	4512	8 33 12·36	129 45 26·3	+2 4·45	− 3 6·8	8 35 16·81	129 42 19·5	5	H.C.R.
1	8 20 46	4539	8 36 8·16	129 51 58·9	−0 51·71	− 9 39·1	8 35 16·45	129 42 19·9	6	J.A.P.
2	8 23 18	4539	8 36 8·13	129 51 58·8	+1 24·69	+ 0 29·5	8 37 32·82	129 52 28·3	10	J.A.P.

Date. 1886.	Sydney M.T. h m s	Star's Name.	Comparison Star's R.A. h m s	Comparison Star's N.P.D. ° ′ ″	Comet's diff. from Star. R.A. m s	Comet's diff. from Star. N.P.D. ′ ″	Comet's Apparent R.A. h m s	Comet's Apparent N.P.D. ° ′ ″	No. of Comp.	Observer.
June 7	8 57 20	4707	8 47 42·30	130 33 52·0	+0 9·85	+ 4 8·5	8 47 52·15	130 38 0·5	50	H.C.R.
11	7 3 34	4803	8 57 6·78	131 25 24·5	−2 1·04	−14 29·9	8 55 5·74	131 10 54·6	10	H.C.R.
13	9 4 4	4803	8 57 6·74	131 25 24·2	+1 35·55	+ 0 57·8	8 58 42·29	131 26 22·0	4	H.C.R.
20	7 43 39	4926	9 10 9·32	131 45 42·2	−0 13·74	+34 40·6	9 9 55·58	132 20 22·8	5	H.C.R.
25	7 57 7	5002	9 17 28·01	131 42 47·4	+0 2·94	+75 47·4	9 17 30·95	132 58 34·8	5	J.A.P.
27	8 33 44	5040	9 20 50·18	133 29 32·1	−0 19·34	−14 28·7	9 20 30·84	133 15 3·3	5	H.C.R.
29	8 30 40	5040	9 20 50·15	133 29 31·7	+2 35·73	+ 1 10·5	9 23 25·88	133 30 42·1	4	H.C.R.

May 2.—At $6^h\ 48^m\ 59^s$ S.M.T. the comet was on the same declination wire as the star.

6.—At $8^h\ 20^m\ 0^s{\cdot}31$ comet passed over a 10 mag. star.

13.—Comet passed over a 9th mag. star at $7^h\ 27^m\ 8^s$ S.M.T.; the position of this star has been obtained by finding the difference by the micrometer between it and 3619 Cape Cat. (1880). The star is the larger member of a double, No. 3954 Herschel's Cape list.

14.—Nucleus about as bright as a 9th mag. star. May 20.—Nucleus small and well defined yet.

22.—Night fine and definition steady; nucleus still visible, though faint.

26.—Hazy night; observations difficult.

June 7.—Comet extremely faint but in a good position for observation with Cape Cat. (1880) 4707.

11.—A very faint nucleus still visible.

20.—*No star near comet within range of micrometer. Position got by circles. 4926 Cape Cat. (1880); observed for index errors.

25.—*No star near. Position got by circles. 5002 Cape Cat. (1880); observed for index errors.

27.—*No star near. Position got by circles. 5040 Cape Cat. (1880); observed for index errors.

July 3.—Comet looked for but not seen. A small star at $9^h\ 29^m\ 9^s$ R.A., 134° 3′ 3″ N.P.D., looked hazy, and was thought to be in comet's haze.

* Probable error of a position determined by means of the circles is $0^s{\cdot}5$ in R.A. and 7″ in Decl.

Comet e, 1885 (*Barnard*).

Date.	Sydney M.T.	Star's Name.	Comparison Star's R.A.	Comparison Star's N.P.D.	Comet's diff. from Star. R.A.	Comet's diff. from Star. N.P.D.	Comet's Apparent R.A.	Comet's Apparent N.P.D.	No. of Comp.	Observer.
1886.	h m s		h m s	° ′ ″	m s	′ ″	h m s	° ′ ″		
June 5	7 59 54	2700 Cape Cat. 1880	5 51 33·46	127 8 29·4	+4 36·06	− 4 12·2	5 56 9·52	127 4 17·3	5	J.A.P.
20	7 6 21	4081	7 58 23·69	140 17 37·6	−1 44·54	+ 4 52·8	7 56 39·15	140 22 30·4	5	H.C.R.
25	7 20 55	4332	8 19 42·95	141 45 46·3	+1 33·60	− 2 16·8	8 21 16·55	141 43 29·5	5	H.C.R.
29	7 51 43	4555	8 37 0·90	142 31 23·1	+0 45·96	− 1 1·5	8 37 46·86	142 30 21·5	12	H.C.R.
July 1	7 17 47	4625	8 41 30·89	142 40 11·6	+3 34·90	+10 3·0	8 45 5·79	142 50 14·7	1	J.A.P.
3	8 16 32	4825	8 59 38·45	143 6 17·4	−7 28·06	+ 2 17·2	8 52 10·39	143 8 34·5	3	H.C.R.

Comet c, 1886.

1886.	h m s		h m s	° ′ ″	m s	′ ″	h m s	° ′ ″		
June 27	7 46 12	Weisse (12) 1039	13 2 7·42	102 30 37·9	− 1 20·61	+ 3 23·6	13 0 46·08	102 34 1·6	8	H.C.R.
July 3	9 10 20	Weisse (12) 1039	13 2 7·36	102 30 37·6	+14 41·00	+270 43·0	13 16 48·00	106 1 20·0	1	H.C.R.

Comet Brooks I. 1886.

1886.	h m s		h m s	° ′ ″	m s	′ ″	h m s	° ′ ″		
July 3	7 5 11	4688 Cape Cat. 1880	8 45 58·22	6 45 16·0	−37 33·00	+153 4·0	8 8 25·00	8 18 20·0	3	J.A.P.

The initials H.C.R. refer to H. C. Russell, and J.A.P. to J. A. Pollock.

June 3.—Barnard seen, but too cloudy for observations.
20.—Barnard in a coarse cluster about equal to a 9th mag. star; diameter of coma about 7″.
26.—Comet *c* seen. July 1.—One satisfactory measure obtained of Barnard.
July 3.—*Comet Brooks I. very close to horizon; position obtained by circles. Comet *c* 1886 very faint; position got by circles.

* Probable error of a position determined by means of the circles is 0ˢ·5 in R.A. and 7″ in Decl.

A transit of Comet Fabry over a 10 mag. star occurred on May 6, 1886. No change in the brightness of the star could be seen as it approached the nucleus or receded from it; and it could be seen distinctly in the edge, but not in the centre. There, although it could be seen that the centre was brighter, owing to the added light of the star, it was not possible to separate one from the other, even with the large telescope, so fairly central was the transit. In fact, the starlight could be seen all the time, but the two points of light could not be separated. The transit occurred at $8^h\ 20^m\ 0^s{\cdot}31$ S.M.T.

A transit of Comet Fabry over the larger member (9 mag.) of a double star, No. 3954, Herschel's Cape list, was observed on May 13, 1886.

As the comet neared the star nothing could be seen of it except the nucleus, which appeared fainter than the star, but not as faint as the small companion of 11 mag. about 8″ off. The transit took place at $7^h\ 27^m\ 8^s$ S.M.T. The comet was lost sight of during transit, although the faint companion could be well seen, and the brightness of the star remained unchanged.

Comet Fabry was first seen in this colony on Saturday, May 1, by persons in many parts of the colony, but light clouds obscured the sky in Sydney. On May 2 I saw it at 6.15 P.M., when the daylight was still strong; it was a conspicuous object, with a tail 4° long. With the telescope the nucleus was well defined, and the coma free from remarkable features. The 11½-inch Equatorial and filar micrometer were used for all observations. The comet was observed by me to pass over a 10th mag. star on May 6th, and over a 9th mag. star on May 13, by Mr. Pollock who was assisting me.

Sydney Observatory:
1886, *July* 12.

Sextant Observations of Fabry's Comet.

(*Communicated by Captain H. Toynbee.*)

Observations made on board the ship "St. Patrick," by Captain James Campbell.

1886, May 2; Lat. 31° 55′ S.; Long. 32° 11′ E.; $6^h\ 45^m$ P.M., A.T.S.

						°	′
Distance of Comet from			*Sirius*	...	...	35	41
,,	,,	,,	*Betelgeuse*	...	...	20	57
,,	,,	,,	*Castor*	...	...	52	50

1886, May 3; Lat. 32° 21′ S.; Long. 31° 3′ E.; $6^h\ 30^m$ P.M., A.T.S.

						°	′
Distance of Comet from			*Sirius*	...	...	20	54
,,	,,	,,	*Castor*	...	...	53	14

Observations made on board the barque "Cassandra," by Captain D. S. Cromarty.

1886, May 2, $9^h\ 25^m$, G.M.T.; Lat. 6° 16′ S.; Long. 29° 44′ W. Comet's position as follows:—

		°	′
Nucleus to	*Rigel*	10	45
„	*Capella*	35	04
„	*Canopus*	54	52

Ephemerides of the Satellites of Saturn, 1886–87. By A. Marth.

(*Continued from p.* 486.)

Differences of Right Ascension and Declination between the three outer Satellites and the centre of Saturn.

Greenwich Noon. 1886.		*Titan.*		*Hyperion.*		*Iapetus.*	
		$\alpha_2-A.$	$\delta-D.$	$\alpha_7-A.$	$\delta_7-D.$	$\alpha_8-A.$	$\delta_8-D.$
		s	″	s	″	s	″
Nov.	20	+ 8·02	−53·0	+ 6·99	− 86·4	+ 0·43	+ 90·2
	21	+11·87	−26·2	+10·95	− 68·8	− 2·93	+ 84·5
	22	+13·93	+ 4·7	+14·23	− 46·8	6·28	78·2
	23	+13·81	+35·0	+16·57	− 21·6	− 9·59	+ 71·4
	24	+11·48	+59·7	+17·75	+ 5·2	12·86	64·0
	25	+ 7·24	+74·6	+17·57	+ 31·7	−16·05	+ 56·2
	26	+ 1·77	+77·1	+15·92	+ 55·6	19·14	47·9
	27	− 4·01	+66·6	+12·77	+ 74·3	−22·10	+ 39·3
	28	− 9·15	+45·1	+ 8·29	+ 85·4	24·93	30·4
	29	−12·83	+16·2	+ 2·85	+ 86·7	−27·59	+ 21·1
	30	−14·52	−15·3	− 2·94	+ 77·5	30·06	11·7
Dec.	1	−14·02	−44·7	− 8·38	+ 58·4	−32·34	+ 2·1
	2	−11·45	−67·7	−12·78	+ 31·9	34·39	− 7·5
	3	− 7·23	−81·1	−15·69	+ 1·5	−36·21	− 17·2
	4	− 1·97	−83·0	−16·90	− 29·2	37·78	26·8
	5	+ 3·58	−73·1	−16·43	− 57·3	−39·09	− 36·2
	6	+ 8·63	−52·7	−14·51	− 80·4	40·13	45·5
	7	+12·42	−24·5	−11·41	− 97·1	−40·89	− 54·5
	8	+14·34	+ 7·5	− 7·47	−106·9	41·37	63·2
	9	+14·01	+38·4	− 3·00	−109·3	−41·56	− 71·5
	10	+11·41	+63·2	+ 1·68	−104·7	41·46	79·4
	11	+ 6·92	+77·6	+ 6·27	− 93·4	−41·07	− 86·8
	12	+ 1·25	+79·0	+10·47	− 76·3	40·39	93·6
	13	− 4·64	+67·1	+14·02	− 54·3	−39·43	− 99·8

Greenwich Noon. 1886.		$\alpha_2 - A.$	$\delta - D.$	$\alpha_1 - A.$	$\delta_1 - D.$	$\alpha_0 - A.$	$\delta_0 - D.$
		s	″	s	″	s	″
Dec.	14	− 9·77	+44·1	+16·64	− 28·6	38·20	105·4
	15	−13·35	+13·9	+18·12	− 0·9	−36·71	−110·3
	16	−14·85	−18·6	+18·22	+ 27·0	34·96	114·5
	17	−14·10	−48·5	+16·82	+ 52·7	−32·97	−117·9
	18	−14 28	−71·4	+13·88	+ 73·6	30·75	120·5
	19	− 6·83	−84·1	+ 9·52	+ 87·0	−28·33	−122·4
	20	− 1·41	−84·8	+ 4·09	+ 90·7	25·71	123·4
	21	+ 4·23	−73·6	− 1·84	+ 83·4	−22·91	−123·7
	22	+ 9·27	−51·7	− 7·54	+ 65·5	19·96	123·1
	23	+12·94	−22·1	−12·30	+ 39·4	−16·87	−121·7
	24	+14·65	+10·8	−15·60	+ 8·4	13·67	119·6
	25	+14·05	+42·2	−17·15	− 23·8	−10·37	−116·6
	26	+11·18	+66·7	−16·98	− 53·6	7·00	112·9
	27	+ 6·38	+80·3	−15·26	− 78·7	− 3·58	−108·4
	28	+ 0·63	+80·4	−12·28	− 97·5	− 0·14	103·2
	29	− 5·31	+67·0	− 8·37	−109·0	+ 3·31	− 97·3
	30	−10·38	+42·4	− 3·86	−113·1	6·75	90·8
	31	−13·78	+11·0	+ 0·89	−109·7	+10·15	− 83·7
1887. Jan.	1	−15·03	−22·3	+ 5·60	− 99·3	13·48	76·0
	2	−14·02	−52·4	+ 9·96	− 82·7	+16·74	− 67·8
	3	−10·94	−74·8	+13·69	− 60·8	19·89	59·1
	4	− 6·29	−86·5	+16·53	− 34·9	+22·92	− 50·0
	5	− 0·74	−86·0	+18·23	− 6·6	25·82	40·5
	6	+ 4·91	−73·3	+18·57	+ 22·2	+28·56	− 30·8
	7	+ 9·86	−49·9	+17·41	+ 49·2	31·12	20·8
	8	+13·34	−19·2	+14·69	+ 71·9	+33·50	− 10·7
	9	+14·80	+14·4	+10·51	+ 87·4	35·68	− 0·4
	10	+13·93	+45·8	+ 5·17	+ 93·3	+37·64	+ 9·9
	11	+10·79	+69·8	− 0·77	+ 87·9	39·37	20·2
	12	+ 5·86	+82·3	− 6·62	+ 71·6	+40·87	+ 30·5
	13	− 0·06	+80·9	−11·63	+ 46·1	42·12	40·6
	14	− 5·96	+65·9	−15·22	+ 15·0	+43·11	+ 50·5
	15	−10·88	+40·0	−17·09	− 17·9	43·84	60·1
	16	−14·06	+ 7·7	−17·18	− 49·1	+44·30	+ 69·4
	17	−15·04	−26·0	−15·68	− 75·8	44·50	78·3
	18	−13·76	−55·8	−12·86	− 96·2	+44·43	+ 86·8
	19	−10·46	−77·4	− 9·06	−109·3	44·08	94·8
	20	− 5·66	−88·0	− 4·62	−114·8	+43·47	+102·2

Greenwich Noon. 1887.	$\alpha_1-A.$	$\delta_1-D.$	$\alpha_2-A.$	$\delta_2-D.$	$\alpha_3-A.$	$\delta_3-D.$
	s	″	s	″	s	″
Jan. 21	− 0·06	−86·1	+ 0·13	−112·7	42·59	109·0
22	+ 5·54	−72·0	+ 4·87	−103·3	+41·45	+115·2
23	+10·34	−47·5	+ 9·30	− 87·5	40·05	120·7
24	+13·60	−16·0	+13·14	− 66·2	+38·41	+125·4
25	+14·78	+17·9	+16·12	− 40·6	36·53	129·4
26	+13·63	+49·0	+18·00	− 12·3	+34·42	+132·6
27	+10·28	+72·1	+18·57	+ 16·9	32·10	134·9
28	+ 5·21	+83·2	+17·66	+ 44·7	+29·58	+136·4
29	− 0·72	+80·4	+15·21	+ 68·6	26·88	137·0
30	− 6·52	+64·1	+11·29	+ 85·7	+24·01	+136·7
31	−11·25	+37·2	+ 6·16	+ 93·6	20·99	135·6
Feb. 1	−14·16	+ 4·3	+ 0·32	+ 90·5	+17·84	+133·6
2	−14·87	−29·2	− 5·54	+ 76·1	14·58	130·7
3	−13·35	−58·4	−10·69	+ 52·1	+11·23	+126·9
4	− 9·88	−79·1	−14·52	+ 21·6	7·82	122·3
5	− 5·00	−88·4	−16·67	− 11·3	+ 4·36	+116·8
6	+ 0·58	−85·2	−17·06	− 43·1	+ 0·88	110·6
7	+ 6·06	−69·9	−15·83	− 70·9	− 2·60	+103·6
8	+10·66	−44·6	−13·25	− 92·6	6·06	95·9
9	+13·67	−12·7	− 9·64	−107·1	− 9·46	+ 87·5
10	+14·59	+21·0	− 5·35	−114·0	12·79	78·6
11	+13·21	+51·4	− 0·71	−113·3	−16·03	+ 69·1
12	+ 9·69	+73·3	+ 3·97	−105·3	19·14	59·1
13	+ 4·57	+83·1	+ 8·39	− 90·8	−22·12	+ 48·7
14	− 1·30	+78·9	+12·27	− 70·6	24·93	37·9
15	− 6·94	+61·6	+15·35	− 46·0	−27·57	+ 26·9
16	−11·43	+34·1	+17·40	− 18·3	30·00	15·7
17	−14·09	+ 1·2	+18·20	+ 10·6	−32·22	+ 4·4
18	−14·56	−31·8	+17·59	+ 38·6	34·21	− 6·9
19	−12·85	−60·0	+15·49	+ 63·2	−35·95	− 18·1
20	− 9·28	−79·5	+11·92	+ 81·8	37·43	29·3
21	− 4·39	−87·6	+ 7·11	+ 91·6	−38·65	− 40·2
22	+ 1·11	−83·4	+ 1·52	+ 90·9	39·60	50·8
23	+ 6·43	−67·3	− 4·26	+ 79·0	−40·27	− 61·1
24	+10·80	−41·6	− 9·47	+ 57·2	40·66	70·9
25	+13·57	− 9·8	−13·50	+ 28·3	−40·76	− 80·3
26	+14·26	+23·3	−15·94	− 3·9	40·58	89·0
27	+12·71	+52·7	−16·66	− 35·6	−40·12	− 97·1
28	+ 9·10	+73·4	−15·78	− 63·8	39·39	104·6

Greenwich Noon. 1887.		$\alpha_s - A.$	$\delta_s - D.$	$\alpha_7 - A.$	$\delta_7 - D.$	$\alpha_8 - A.$	$\delta_8 - D.$
		s	″	s	″	s	″
Mar.	1	+ 4·00	+81·9	−13·52	− 86·5	−38·40	−111·3
	2	− 1·75	+76·7	−10·21	−102·4	37·15	117·2
	3	− 7·20	+58·7	− 6·17	−110·8	−35·65	−122·4
	4	−11·45	+31·2	− 1·72	−111·7	33·92	126·7
	5	−13·87	− 1·2	+ 2·83	−105·5	−31·97	−130·1
	6	−14·15	−33·4	+ 7·18	− 92·7	29·81	132·6
	7	−12·32	−60·7	+11·07	− 74·3	−27·46	−134·3
	8	− 8·71	−78·9	+14·25	− 51·1	24·95	135·1
	9	− 3·88	−85·9	+16·48	− 24·7	−22·28	−135·0
	10	+ 1·48	−80·9	+17·54	+ 3·3	19·48	134·1
	11	+ 6·62	−64·4	+17·28	+ 30·9	−16·57	−132·2
	12	+10·78	−38·7	+15·59	+ 55·9	13·56	129·5
	13	+13·34	− 7·5	+12·46	+ 75·6	−10·48	−126·1
	14	+13·86	+24·8	+ 8·08	+ 87·4	7·35	121·9
	15	+12·20	+53·0	+ 2·81	+ 89·3	− 4·18	−116·9
	16	+ 8·57	+72·6	− 2·78	+ 80·5	− 1·00	111·2
	17	+ 3·55	+80·0	− 8·00	+ 61·5	+ 2·18	−104·8
	18	− 2·06	+74·1	−12·20	+ 35·0	5·33	97·8
	19	− 7·30	+55·9	−14·96	+ 4·4	+ 8·43	− 90·3
	20	−11·33	+28·7	−16·07	− 26·7	11·46	82·3
	21	−13·57	− 3·1	−15·61	− 55·0	+14·42	− 73·8
	22	−13·71	−34·2	−13·76	− 78·4	17·28	64·9
	23	−11·82	−60·2	−10·82	− 95·5	+20·03	− 55·6
	24	− 8·24	−77·4	− 7·10	−105·5	22·65	46·1
	25	− 3·50	−83·6	− 2·91	−108·4	+25 13	− 36·3
	26	+ 1·71	−78·1	+ 1·46	−104·3	27·45	26·4
	27	+ 6·66	−61·5	+ 5·71	− 93·7	+29·60	− 16·4
	28	+10·64	−36·2	+ 9·60	− 77·3	31·58	− 6·3
	29	+13·03	− 5·7	+12·88	− 56·3	+33·37	+ 3·8
	30	+13·43	+25·5	+15·32	− 31·6	34·95	13·8
	31	+11·73	+52·6	+16·66	− 4·9	+36·33	+ 23·7
April	1	+ 8·14	+71·0	+16·80	+ 22·0	37·50	33·4
	2	+ 3·22	+77·6	+15·57	+ 47·0	+38·45	+ 42·8
	3	− 2·22	+71·3	+12·96	+ 67·7	39·18	51·9
	4	− 7·27	+53·3	+ 9·06	+ 81·5	+39·68	+ 60·7
	5	−11·12	+26·6	+ 4·19	+ 86·2	39·95	69·1
	6	−13·21	− 4·2	− 1·15	+ 80·7	+39·99	+ 77·1
	7	−13·28	−34·2	− 6·33	+ 65·1	39·81	84·5
	8	−11·39	−59·1	−10·70	+ 41·5	+39·40	+ 91·5
	9	− 7·87	−75·4	−13·79	+ 13·0	38·77	97·9

Greenwich Noon. 1887.	$a_3-A.$	$\delta_3-D.$	$a_7-A.$	$\delta_7-D.$	$a_8-A.$	$\delta_8-D.$
	s	″	s	″	s	″
April 10	− 3·25	−81·0	−15·34	− 16·8	+37·92	+103·6
11	+ 1·81	−75·2	−15·35	− 44·9	36·85	108·7
12	+ 6·59	−58·9	−13·97	− 68·9	+35·57	+113·2
13	+10·40	−34·2	−11·47	− 87·1	34·10	117·0
14	+12·68	− 4·6	− 8·13	− 98·9	+32·43	+120·1
15	+13·02	+25·5	− 4·24	−103·8	30·58	122·5
16	+11·32	+51·5	− 0·09	−101·9	+28·55	+124·1
17	+ 7·80	+69·0	+ 4·04	− 93·8	26·36	125·0
18	+ 3·01	+75·1	+ 7·92	− 80·0	+24·03	+125·1
19	− 2·26	+68·6	+11·29	− 61·2	21·57	124·5
20	− 7·14	+50·9	+13·93	− 38·6	+18·98	+123·1
21	−10·85	+25·1	+15·62	− 13·5	16·29	121·0
22	−12·85	− 4·7	+16·18	+ 12·4	+13·51	+118·1
23	−12·89	−33·6	+15·46	+ 37·2	10·66	114·6
24	−11·04	−57·5	+13·39	+ 58·6	+ 7·75	+110·4
25	− 7·61	−73·0	+10·04	+ 74·2	4·80	105·5
26	− 3·12	−78·2	+ 5·62	+ 81·7	+ 1·84	+100·0
27	+ 1·78	−72·4	+ 0·57	+ 79·7	− 1·12	93·9
28	+ 6·42	−56·5	− 4·53	+ 67·8	− 4·07	+ 87·3
29	+10·12	−32·6	− 9·05	+ 47·5	6·98	80·1
30	+12·32	− 4·0	−12·47	+ 21·6	− 9·83	+ 72·5
May 1	+12·65	+25·0	−14·48	− 6·7	12·61	64·5
2	+10·99	+50·0	−15·01	− 34·2	−15·31	+ 56·2
3	+ 7·56	+66·7	−14·16	− 58·5	17·89	47·5
4	+ 2·91	+72·4	−12·14	− 77·8	−20·35	+ 38·6
5	− 2·21	+66·1	− 9·22	− 91·2	22·67	29·5
6	− 6·95	+48·9	− 5·67	− 98·3	−24·83	+ 20·3
7	−10·56	+23·9	− 1·76	− 98·9	26·82	11·0
8	−12·51	− 4·7	+ 2·25	− 93·3	−28·63	+ 1·7
9	−12·56	−32·6			30·25	− 7·6
10	−10·77	−55·5			−31·67	− 16·7
11	− 7·45	−70·5			32·88	25·6
12	− 3·09	−75·5			−33·86	− 34·3
13	+ 1·68	−69·9			34·63	42·7
14	+ 6·20	−54·5			−35·17	− 50·8
15	+ 9·82	−31·4			35·47	58·5
16	+11·99	− 3·9			− 35·54	− 65·8
17	+12·33	+24·2			35·39	72·5
18	+10·74	+48·3			−35·01	− 78·6

Ephemeris of the Satellite of Neptune, 1886–87. By A. Marth.

Greenwich Noon. 1886.	P′	*a*	*b*	*u*−U	Diff.	U	B
	°	″	″	°	°	°	°
Sept. 30	323·87	16·78	8·07	35·96	612·42	131·25	−28·77
Oct. 10	323·73	16·85	8·09	288·38	·37	131·44	28·70
20	323·54	16·90	8·10	180·75	·33	131·67	28·62
30	323·35	16·94	8·09	73·08	·30	131·93	28·53
Nov. 9	323·12	16·97	8·08	325·38	·28	132·22	28·42
19	322·89	16·97	8·05	217·66	·27	132·51	28·31
29	322·67	16·96	8·01	109·93	·27	132·80	28·19
Dec. 9	322·46	16·93	7·97	2·20	·29	133·08	28·08
19	322·27	16·89	7·92	254·49	·32	133·33	27·97
29	322·10	16·83	7·87	146·81	·36	133·55	27·88
1887 Jan. 8	321·97	16·75	7·81	39·17	612·39	133·72	−27·80
18	321·87	16·67	7·76	291·56	·44	133·84	27·74
28	321·82	16·58	7·71	184·00	·50	133·90	27·71
Feb. 7	321·81	16·49	7·66	76·50	·56	133·91	27·70
17	321·85	16·39	7·62	329·06	·62	133·86	27·70
27	321·93	16·30	7·59	221·68	·68	133·75	27·73
Mar. 9	322·06	16·21	7·56	114·36	·73	133·58	27·79
19	322·23	16·13	7·54	7·09	612·78	133·36	27·87
29	322·43	16·05	7·53	259·88		133·09	−27·97

P′ angle of position of the minor axis of the satellite's apparent orbit, in the direction of superior conjunction.

a, *b*, major and minor semi-axes of the apparent orbit.

u−U, longitude of the satellite in its orbit, reckoned from the point which is in superior conjunction with the planet or in opposition to the Earth.

U + 180°, planetocentric longitude of the Earth, reckoned in the satellite's orbit from the ascending node on the celestial equator.

B, planetocentric latitude of the Earth above the plane of the satellite's orbit.

The values of P′, *a*, *b* and *u*−U are to be interpolated for the times for which the apparent positions of the satellite are required, the equation of light being already taken into account in the ephemeris, and the position-angles *p* and distances *s* are then found by means of the equations.

$$s \sin (P' - p) = a \sin (u - U)$$
$$s \cos (P' - p) = b \cos (u - U).$$

The satellite moves in the direction of *de*creasing position-angles, and will be at its greatest elongations and at its nearest

conjunctions with the planet about the following hours, Greenwich mean time:—

	Super. Conj. $p=$ P′ $s=$ *b*		*sp.* Elong. P′−90° *a*		*Infer.* Conj. P′−180° *b*		*nf.* Conj. P′+90° *a*	
1886.		h		h		h		h
Sept.	29	9·9	Sept. 30	21·2	Oct. 2	8·4	Oct. 3	19·7
Oct.	5	7·0	Oct. 6	18·3	8	5·5	9	16·8
	11	4·1	12	15·3	14	2·6	15	13·9
	17	1·2	18	12·4	19	23·7	21	11·0
	22	22·3	24	9·5	25	20·8	27	8·1
	28	19·1	30	6·6	31	17·9	Nov. 2	5·2
Nov.	3	16·5	Nov. 5	3·7	Nov. 6	15·0	8	2·3
	9	13·6	11	0·8	12	12·1	13	23·4
	15	10·7	16	22·0	18	9·2	19	20·5
	21	7·8	22	19·1	24	6·4	25	17·6
	27	4·9	28	16·2	30	3·5	Dec. 1	14·7
Dec.	3	2·0	Dec. 4	13·3	Dec. 6	0·6	7	11·9
	8	23·1	10	10·4	11	21·7	13	9·0
	14	20·2	16	7·5	17	18·8	19	6·1
	20	17·4	22	4·6	23	15·9	25	3·2
	26	14·5	28	1·7	29	13·0	31	0·3
1887.								
Jan.	1	11·6	Jan. 2	22·8	Jan. 4	10·1	Jan. 5	21·4
	7	8·6	8	19·9	10	7·2	11	18·5
	13	5·7	14	17·0	16	4·3	17	15·6
	19	2·8	20	14·1	22	1·4	23	12·6
	24	23·9	26	11·2	27	22·4	29	9·7
	30	21·0	Feb. 1	8·2	Feb. 2	19·5	Feb. 4	6·8
Feb.	5	18·0	7	5·3	8	11·6	10	3·8
	11	15·1	13	2·3	14	13·6	16	0·9
	17	12·1	18	23·4	20	10·6	21	21·9
	23	9·2	24	20·4	26	7·7	27	18·9
Mar.	1	6·2	Mar. 2	17·4	Mar. 4	4·7	Mar. 5	15·9
	7	3·2	8	14·5	10	1·7	11	13·0
	13	0·2	14	11·5	15	22·7	17	10·0
	18	21·2	20	8·5	21	19·7	23	7·0

Since the last ephemeris of the satellite was published, some weighty evidence concerning the position of the plane of its orbit has become available by the publication of Appendix II. of the Washington Observations for 1881, containing Asaph Hall's paper, "Orbit of the Satellite of Neptune." The question of the position of the plane is a perplexing one. When, in 1865,

I had made a determination of the orbit from the Malta observations of 1863–64, it was to me a puzzle what could be the cause that the values of the node and inclination which, ten years before, I had deduced from Lassell's observations of 1852 ($N = 178°{\cdot}74$, $I = 126°{\cdot}14$ for 1852·9) should differ from those of the later determination ($N = 181°{\cdot}49$, $I = 123°{\cdot}86$ for 1864·0) considerably more than the agreement of the measurements of each series, as shown by the probable errors, seemed to permit. The circumstance, that in 1863–64 the form of the apparent orbit was that of a narrow ellipse, favoured the determination of the inclination and node, but was disadvantageous for fixing the satellite's orbital longitude, which was, indeed, left practically indeterminate. Hence my investigation could be only a preliminary one, till further observations should allow the question of orbital longitude to be settled, and I abstained the more readily from publishing merely preliminary results, as at that time I was led to expect that before long I should myself have the opportunity of making the observations requisite for a more complete investigation. When Newcomb's paper, "The Uranian and Neptunian Systems," forming Appendix I. of the Washington Observations for 1873, became known to me, I was surprised that his values of the node and inclination ($N = 183°{\cdot}03$, $I = 121°{\cdot}70$ for 1874·0) differed from those derived from the Malta observations of 1863–64 in the same direction as these differed from the values found from the earlier series. Making ample allowance for any plausible or possible errors of the Malta observations, I satisfied myself that in 1863–64 the satellite could not have moved in the plane deduced from the Washington observations. However, in the ephemerides published in the *Monthly Notices*, I thought it best to adopt Newcomb's determination, leaving the difficulty to be cleared up by the evidence of further observations. The measurements from other observatories have hitherto been too sporadic to be of real help. But Asaph Hall's "Orbit of the Satellite of Neptune" contributes sufficient evidence to justify a public statement in order to call the attention of astronomers to the consideration of a very perplexing question.

If Hall's values of the node and inclination ($N = 184°{\cdot}316$, $I = 120°{\cdot}052$ for 1883·0) and the values before-mentioned are transferred from the planes parallel to the terrestrial equator, to which they refer, to the plane of the orbit of Neptune ($N_0 = 3°{\cdot}568$, $I_0 = 22°{\cdot}339$ for 1880·0), the four determinations furnish the following values of the node and inclination of the satellite's orbit in reference to that of the planet, the longitudes of the node being reckoned along the planet's orbit from the point which precedes the ascending node of the orbit on the ecliptic by $130°{\cdot}437$, the ecliptical longitude of this node. If reckoned from the ascending node N_0 of the planetary orbit on the equator, the longitudes of the node are $3°{\cdot}29$ less. The probable errors of the values amount only to a few tenths of a

degree, and may be left unnoticed at present, as they and their differences do not affect the question at issue.

		Long. of Node on Neptune's Orbit.	Inclination of the two Orbits.		
Malta	1852	176°·20	148°·33	or 31°·67	if the satellite's motion is reckoned as retrograde.
	1864	180·41	146·19	33·81	
Washington	1874	182·59	144·04	35·96	
	1883	184·31	142·38	37·62	

How are the differences of these values to be explained?

Can they be accounted for by any plausible or possible systematic errors in the observations?

Or do they represent real changes in the position of the plane of the orbit, the effect of some disturbing force which must be found out and traced to its source? What plausible cause can produce such changes? That is the question.

In order to proceed with due caution in this investigation, it is obviously desirable that the available evidence should be strengthened. Considering that a number of sufficiently powerful telescopes, firmly mounted, and provided with superior micrometers, are in existence, is it too much to ask that they should be employed during the present apparition of Neptune at every favourable opportunity in measuring the position-angle and the distance of the satellite (or, if both co-ordinates cannot be got, at least the position-angle), so that, from their united evidence, not only the elements of the orbit may be determined for the present time, but also some evidence may be gained for the consideration of the question of systematic errors? Observers must, of course, be on their guard against any preoccupation or bias, and it may be hoped that the publication of the observations will not be needlessly delayed.

The ephemeris has been computed with the same elements as in preceding years, so that the satellite is assumed to move in the plane of Newcomb's elements for 1874. The variations of the ephemeris if the plane of Hall's elements for 1883, or that derived from the Malta observations, is substituted may be recognised from the following data:—

	Washington 1883.			Malta 1864.		
	P′	U	B	P′	U	B
	°	°	°	°	°	°
1886, Sept. 30	321·74	132·90	−29·30	326·52	129·20	−27·90
Nov. 29	320·53	134·43	28·67	325·34	130·77	27·39
1887, Jan. 28	319·68	135·52	28·15	324·49	131·89	26·95
Mar. 29	320·29	134·72	−28·44	325·09	131·07	−27·18

Errata in Mr. Tebbutt's paper, "Observations of Double Stars at Windsor, N. S. Wales," in *Monthly Notices*, vol. xlvi :—

Page 51.—Position angle of Lac. 1181, *for* 227°·5 *read* 327°·5.
,, 52.—*For* o Argûs *read* υ Argûs.

Erratum in Mr. Backhouse's paper, "The Great Shower of Andromedes, 1885," in *Monthly Notices*, vol. xlvi :—

Page 310, last line of Table I., in column "duration of watch," *for* 78 *read* 98.

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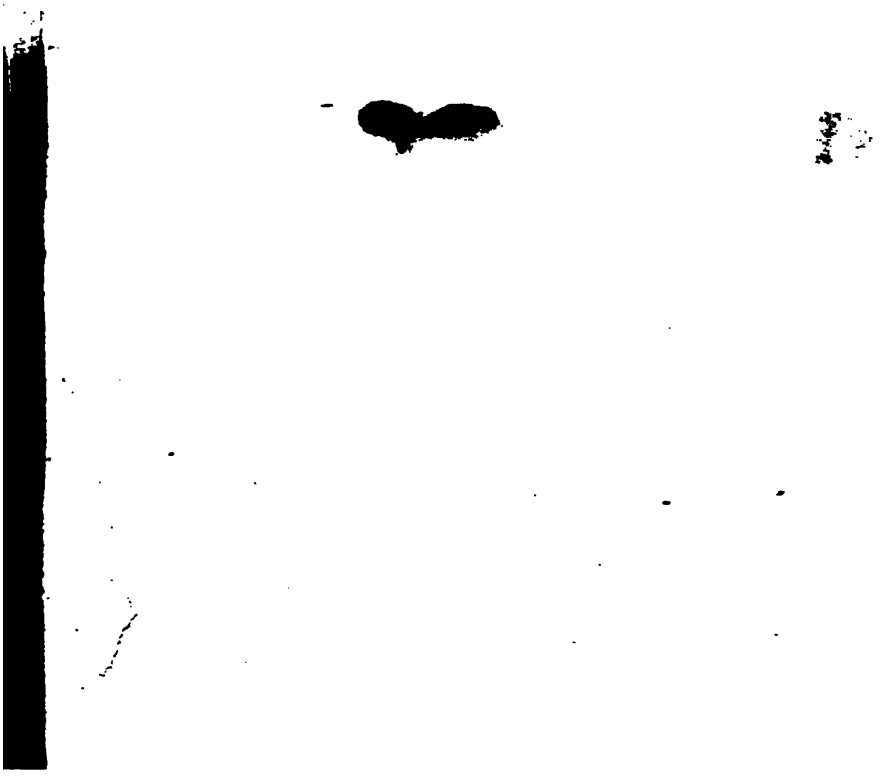

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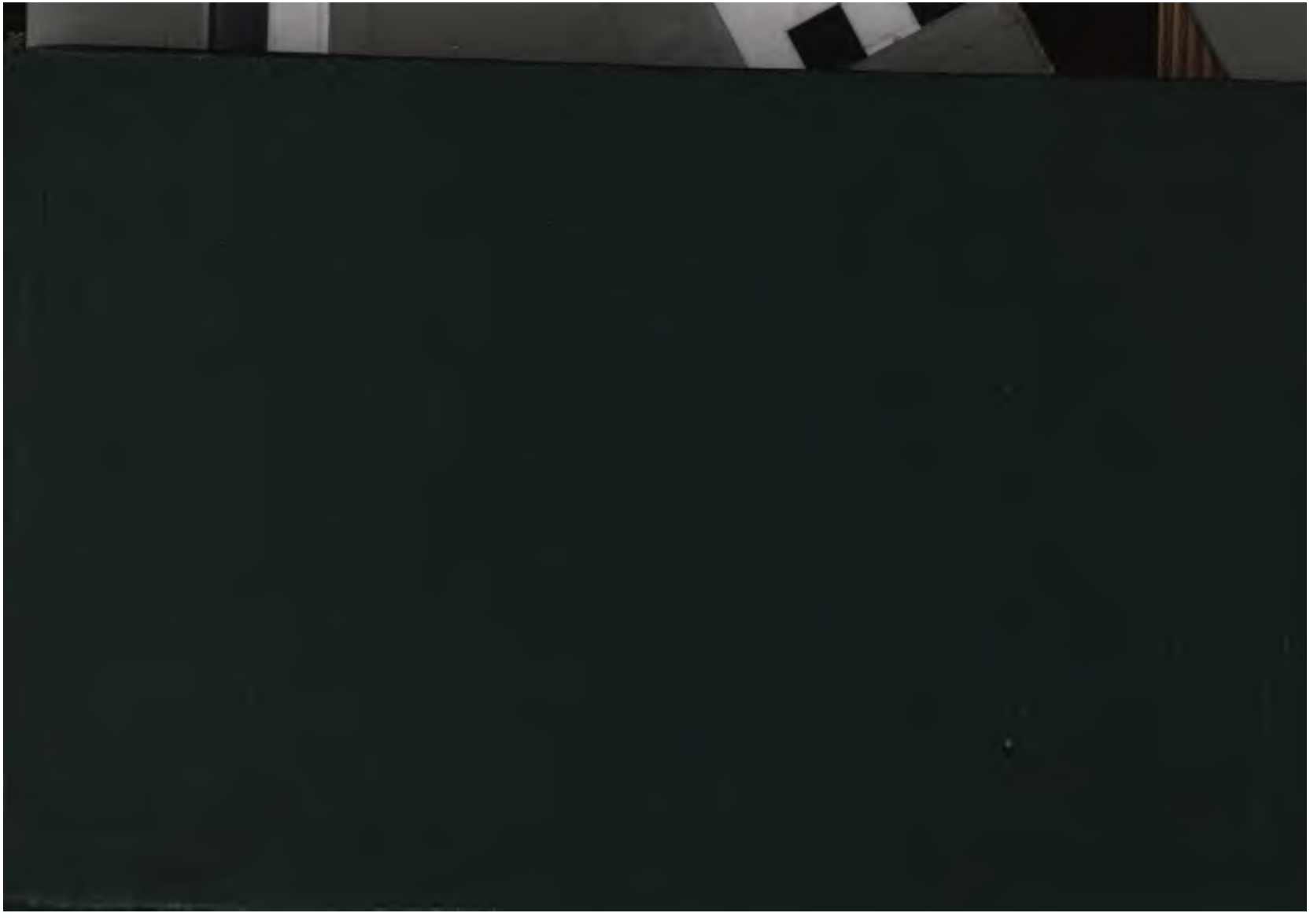
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